PROCEEDINGS OF THE
ROYAL SOCIETY OF
QUEENSLAND

Supplement to the Queensland Government Gazette of Saturday, 3rd November, 1877.—No. 84.

Queensland.

'ANNO QUADRAGESIMO PRIMO

VICTORIÆ REGINÆ.

No. 21.

An Act to Regulate the Fisheries in Queensland Waters.

[ASSENTED TO 5TH NOVEMBER, 1877.

Preamble. WHEREAS it is desirable to make provision for the preservation of the fish in Queensland waters and to regulate the fisheries therein Be it therefore enacted by the Queen's Most Excellent Majesty by and with the advice and consent of the Legislative Council and Legislative Assembly of Queensland in Parliament assembled and by the authority of the same as follows—

Interpretation. 1. In the construction of this Act—

The word "boat" shall include any punt or vessel of any description

The word "waters" shall include salt and fresh waters other than such as are the property of any private person.

Size of nets. 2. No person shall except as hereinafter provided take or attempt to take fish with any net having a mesh of less dimensions than one inch and a-quarter in extension from knot to knot (the measurement to be made on each side of the square) or five inches measured round each mesh when wet

For the purpose of catching garfish and prawns it shall nevertheless be lawful to use a net having meshes in the bunt thereof of dimensions not less than nine-sixteenths of an inch in extension from knot to knot measured on each side of the square or two inches and a-quarter measured round each mesh when wet and having meshes in the wings of the net of dimensions not less than five-eighths of an inch in extension from knot to knot or not less than two inches and one half round the mesh measured as aforesaid Provided that the bunt of such net be not longer than eight fathoms

Every

2017 VOLUME 122

MUSEUMS VICTORIA
0 5 FEB 2019

VOLUME 122

PROCEEDINGS OF THE

ROYAL SOCIETY OF QUEENSLAND

Editor: Dr. B. Pollock

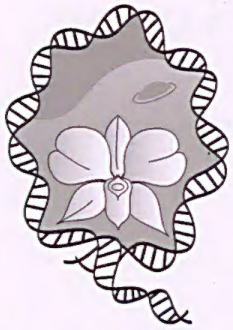
Special thanks are extended to the anonymous referees who reviewed papers submitted for publication in this volume of the *Proceedings*.

Museum Victoria
76319

2017

The Royal Society of Queensland Inc.

Queensland's first scientific society
Established 1883



Royal Society of Queensland

Patron
His Excellency the Governor of Queensland
the Honourable Paul de Jersey AC

COVER ILLUSTRATION
The Preamble of the *Queensland Fisheries Act 1877* which provided for the first time in Queensland measures to preserve fish and to regulate fisheries. Amongst other provisions, this Act specified minimum sizes for the commonly-caught fish, and required commercial fishers to be licenced and use nets of limited dimensions. This year (2017) is the 140th anniversary of fisheries legislation in Queensland. The foresight of those early colonial politicians to protect and manage the natural resources of Queensland is acknowledged.

© Royal Society of Queensland Inc.
PO Box 6021, St Lucia 4067

National Library of Australia card number
ISSN 0080-469X

Royal Society of Queensland

The Royal Society of Queensland has a remarkable history and highly regarded status. It was established in 1883, with royal patronage first granted in 1885, and this has continued unbroken to the present time. The Governor of Queensland His Excellency The Honourable Paul de Jersey AC is the present Patron.

The aim of the Royal Society of Queensland is to progress the natural sciences and scientific knowledge of the natural resources of Queensland. The Society supports scientists and scientific endeavour through advocacy, policy analysis and opinion, scientific seminars and public lectures. The Society is a non-partisan, secular, learned society. The centrepiece of the Society is the production of the scientific journal, *Proceedings of the Royal Society of Queensland*, which is published annually.

Membership is encouraged and open to any person interested in the progress of the natural sciences in Queensland. Members of the Society receive a copy of the Proceedings each year as well as regular newsletters and other information. Membership enquiries should be directed to the Secretary, Royal Society of Queensland, PO Box 6021, St Lucia Q4067. Email rsocqld@gmail.com

Proceedings of the Royal Society of Queensland

The *Proceedings of the Royal Society of Queensland* publishes natural history topics **of relevance to Queensland**, with a very broad range of subjects including biodiversity, conservation, use, management and economic significance of natural resources. All aspects of botany, geology, hydrology and zoology, the biology, impacts and management of introduced species, biomedicine studies and papers on culture and heritage. The journal will also publish papers on general science, including science-related policy, education and philosophy.

All submitted papers are peer reviewed. The following types of manuscripts are considered:
(i) **Scientific Papers** – Full papers containing substantial new data or a substantial review.
(ii) **Short Communications** – Primary research articles reporting discrete items of completed research or topical reports of developments relevant to natural resources in Queensland.
(iii) **Thesis Abstracts** – These short papers aim to disseminate and summarise work performed at the Honours, MSc and PhD level.
(iv) **Opinion Papers and Historical Papers** – Opinion pieces are written as a perspective, not a formal review. These types of papers are of interest to a broad readership, with an emphasis on Queensland relevance.
(v) **Book Reviews** – Authors of books on topics within the scope of PRSQ may contact the Editor to arrange for a book review.

Authors are urged to follow the instructions given in the Guide to Authors which is available on the Society website. Failure to do so may necessitate the return of the manuscript to the author for style revision, and associated delays in publication. The present timelines cover the production of a single volume each year, and require authors to submit their papers to the Editor by 1 July. Following initial appraisal by the Editor, the papers are peer-reviewed by at least two anonymous referees who are experts in the subject. Authors are provided with the reports of referees, and are expected to complete a timely revision where this is necessary. The paper is then typeset and returned to the author for final checking prior to publication. The completed annual volume is published and distributed in December each year. There are no page charges to authors for publication in the *Proceedings of the Royal Society of Queensland*. Authors will be sent a PDF version of the final published paper.

Royal Society of Queensland Council 2016 – 2017

President	Dr G. Edwards
Immediate Past-President	Mr C. Walton
Secretary	Dr B. Lawson
Treasurer	Dr W.J.F. McDonald
Editor	Dr B. Pollock
Committee	Professor A. Arthington, Dr R. Hynes, Nita Valerie Sharp

Typeset by Rennie Fletcher
Printed by LitSupport

ARE THERE RECEPTIVE RECEPTORS? BUILDING SCIENCE INTO POLICY AND PLANNING PRESIDENTIAL ADDRESS 2016

EDWARDS, G.

INTRODUCTION

"I'm really angry that the government isn't listening to us, to the evidence we've been providing to them since 1998", proclaimed Prof Terry Hughes of James Cook University in March 2016 after observing coral bleaching over some 1000 km of the northern Great Barrier Reef (McCutcheon 2016).

In this commentary for 2016 on an aspect of Queensland science, I wish to examine whether the preconditions for members of Parliament to heed environmental warnings are in place. These include scientific knowledge packaged in a digestible format; receptive advisors familiar with scientific jargon; and effective forums by which expert knowledge is injected into government policy or decisions.

DEFINITIONS

Before checking whether there is indeed a problem, some terms need clarifying. 'Science' in this paper will be confined to the natural sciences (although the scope of the interests of the Royal Society of Queensland is not so confined). 'Policy' includes legislation and budgets as well as high strategy. 'Economics' refers to the neoclassical formulation which should be differentiated from distortions promulgated by political culture warriors and columnists in the financial press. 'NRM' is 'natural resource management', the planning, allocation and management of land, water, vegetation, minerals and other land-related resources.

'The government' is an ambiguous term. It embraces elected parliamentarians; ministers; their political staffers; statutory boards and advisory committees; and officers within the public service, in three geographic levels. These cohorts are recruited according to distinctive criteria and fraternise with distinctive networks holding distinctive world views. This address deals mainly with the Queensland level, but touches on some national conditions.

IS THERE A PROBLEM?

LACK OF RESPECT FOR SCIENTISTS

It is easy to form the conclusion that Australian scientists are not nowadays being given the respect that they deserve. Evidence lies for example in the successive cutbacks to staff and budgets at CSIRO over several years and forced redundancy in 2016 of eminent climate scientists (Jones 2016; Manning 2016).

Recent see-sawing over the future of the Macquarie Island Research Station is a relevant case example. In September 2016 the Commonwealth announced that the station would not operate year-round, as it has done since 1948. The announcement "prompted an outcry from the scientific community" (Anon 2016) and four days later the minister backtracked. Then in October an additional $50 million was found to build a permanently manned station. No scientific program can thrive under such stop-start conditions and nor should we be squandering the time of our best scientific scholars in having to defend the worth of facilities for scientific research.

Looking more broadly than just science, an apparent creeping disregard for rational, evidence-based policy analysis in general is now on display in the United States' political arena and also in the Commonwealth Parliament as elected representatives publicly advocate policies seemingly based on preconceived ideological positions, such as on climate change and on the prospect of building more coal-fired power stations. Public statements by elected members and media commentators articulating a 'conservative' policy agenda seem to conflate scientists who speak publicly within their field of expertise with 'radical environmental activists', even when both are simply reporting scientific data. If any readers doubt the capacity of the nation's leading broadsheet *The Australian* to distort environmental warnings, it should be dispelled by a single lead article on

4 June 2016 accusing 'activist scientists' and 'lobby groups' of exaggerating the bleaching mentioned in the opening paragraph of this article (Readfern 2016). This journalism is wilfully shooting the messenger and is corrosive for science and for intelligent public debate alike.

While discounting messages from science, public policy is placing undue faith in economics. Recent headline policy reports such as the Commonwealth's 2015 *Energy White Paper* and 2016 *Australian Infrastructure Plan* and Queensland's 2016 *Draft Regional Plan* reflect a shallow optimism that somehow market forces will reconcile the competing pressures in the respective field. Even a cursory glimpse into the rich contemporary scientific literature of resilience, complexity, ecosystem services and interconnectedness leaves one despondent at the poverty of present-day economistic policy and policy debate.

DECLINE IN ENVIRONMENTAL CONDITION

Most Queenslanders who fish or camp or tour around the outdoors can recite anecdotes of decline in places they love. I will mention just Godwin Beach, on the mainland near Bribie Island. The flocks of migratory wading birds that used to fly into the cove every October are sparser this year, having suffered from filling of wetlands around Moreton Bay and harassment by wandering dogs, not to mention tidal reclamation in East Asia. Such birds as do make the journey this year may be confronted with festoons of toxic *Lyngbya* algae over the mud flats where they should be foraging. *Lyngbya* is evidence of acidified and polluted run-off from canal estates and stormwater drains around the northern bay.

We elect and fund governments to solve collective problems that are too complex or large in scale to be amenable to individual or market-based solutions. Governments are failing in this responsibility. Scientists despair at the slowness of progress in even acknowledging the seriousness of the cascading assaults we are now witnessing on the life-support systems of the planet, let alone progress in remedial action.

PACKAGING SCIENTIFIC INFORMATION

Scientists, politicians and policy analysts communicate to different audiences via different media using distinctive styles of language (Edwards 2014). Original scientific information comes packaged in an academic format very different from that in which policy is formulated. It is also collected in reductionist 'silos' which can become even more specialised as knowledge expands exponentially.

So burgeoning scientific information must be continually translated into terms that the political and policy arenas can digest, regardless of how well educated in science the politicians and policy analysts involved may be.

Translation embraces three main functions:

- *co-ordinating* disparate information from various sources; merging and aligning it;
- *changing scale*, zooming in or out from the scale of the data to the scale of the policy or decision that is to be finalised;
- *interpreting* information, tracing cause and effect, explaining the implications, identifying what needs to be done to remedy the problems uncovered.

Coordination, the first item, is required in two dimensions: *horizontal*, between departmental portfolios, scholarly disciplines, citizen science and interest groups; and *vertical*, between policy and operations. Horizontal coordination is an essential precondition for prudent durable policy. Vertical coordination (not further discussed in this paper) is an essential precondition for effective implementation, as it facilitates alignment between those who make policy, those who control the purse strings, those with the skills and knowledge and those with authority to make things happen.

Mostly, horizontal coordination within government happens out of public view. A complex network of ministerial committees, interdepartmental committees, statutory officers, advisory boards, working groups and taskforces continually debates issues, prepares public and unpublished reports and compiles advice for decision-makers. When all goes smoothly, the end result is effective legislation, coherent policy, consistent decisions – and a peaceful, prosperous and environmentally sustainable society.

It is easy to underestimate the complexity of the procedures to achieve these end results. "Coordination is the hardest task of government", opined Glyn Davis (formerly Director-General, Office of Cabinet) and Patrick Weller in 1993.

Only government has a mandate to coordinate disparate parties across sectors of society. It is almost impossible for outsiders to comprehend just how difficult is this role and just how unrelenting is the pressure upon ministers and officers to cope with coordinating even routine statutory and administrative business, without confronting complex new problems for which there is no obvious or inexpensive remedy.

DISTINCTIVE SKILL SETS REQUIRED

To broker the translation of science into policy, it is not essential to be a scientist and is certainly not sufficient; for scientists are not even necessarily good at this process, which requires familiarity with the unique disciplines of public administration and policy analysis. For some global issues, translation of scientific information is primarily a matter of another specialist discipline, intergovernmental relations.

Policy analysis is studied by very few undergraduates and is mostly learned on the job within public authorities. It is not a job for amateurs or ideologues, which is why the model of a technically competent Westminster public service with secure tenure and recruited on merit rather than patronage evolved. The signature reforms date from 1854 in England and would have been in front of mind when the Queensland colonial service was established in 1859, contemporaneously with the Philosophical Society of Queensland, forerunner to The Royal Society of Queensland.

To assess the receptiveness of our policy apparatus to scientific warnings, it is necessary to trace some trends in public administration since the 1980s and to examine how the traditional model of a permanent public service has been undermined.

RECEPTIVE ADVISORS WITH APPROPRIATE SKILLS?

The Victorian government in 1982 then the Hawke government in 1983 imported (from the USA) a model of public administration called 'new managerialism'. Central to the model is a corps of generalist managers with portable skills who would be mobile across the public service and would be more responsive than the traditional Westminster service to political direction. The initiative was intended to counter the reputation of the public service as being slow, conservative, rule-bound and liable to frustrate the will of elected governments. With the experience of more than 30 years, it is now plain that this model has resulted in dumbed-down and politicised analytical capacity.

It is possible to trace the origin of this reform agenda to mechanical neoclassical models of the economy and mechanical models of human behaviour. They have been based on a rationalist rather than an organic conception of society: outcomes can be specified, functions can be neatly divided into goods and services, then into contractual parcels amenable to market competition with performance being measurable; and the human agents involved can be motivated by pecuniary rewards.

At first glance, one might assume that a model of public administration based on rational interaction would form a congenial home for rational scientific knowledge, which relies on facts and figures rather than non-predictable emotions. It hasn't turned out that way for reasons which warrant an article by itself, but lie partly in the very bounded rationality of neoclassical economics (the environment, social justice and high order cultural values are external to its models); and partly lie in science's sharper awareness of the inter-dependence of agents and phenomena in complex systems.

Although rationalist in its own mindset, the new managerialism concedes pre-eminence in determining policy to ministers who are subject to political forces that lie outside rational calculation and are likely to be insensitive to scientific influence. Under new managerialism, elected ministers determine what is in the public interest, a mindset that seems now deeply entrenched across Australian governments. Peter Shergold, one time Secretary of the Department of Prime Minister, articulated this view: "Now, at the end of the day, it is the government, the elected government, not the public service, that decides on national interest" (Burgess 2004) and even more authoritatively, the Australian Public Service Commission (2006) declared: "...the elected Government alone has the authority to determine the public interest in terms of policies and programmes, while public servants assist Governments to deliver that policy agenda and those priorities". This blurs the long-standing distinction between the interest of the *public* and the interest of the *government* and portrays the role of the public service as simply one of implementation. There seems no room within

this model for original research by public service scientists and no room for frank and fearless advice about the implications of contemporary scientific knowledge for policy. This model cannot plausibly be regarded as receptive to scientific information, unless the elected members themselves are immersed in scientific discourse, which time and training do not allow.

An earlier Secretary, Michael Keating, wrote (1999), in language worthy of *Yes Minister*'s Humphrey Appleby, that the public servant's responsibility for the public interest lay in overseeing an ethical process. He doubted that the public service can be "some sort of independent guardian of the public interest in good policy" because advocates of that view have failed to define the public interest in a way that can usefully guide action. It is unclear how this impediment evaporates when the locus for making the determination shifts to ministers, who usually commence handicapped by a lack of background in the portfolios they have been allocated, and throughout their tenure are badgered by lobbyists seeking private advantage.

In any case, Sir Humphrey was a self-declared "moral vacuum"; and a moral vacuum is simply not good enough in an era when multiple manifestations of environmental breakdown such as climate change loom as moral, not just economic, challenges.

While it is easy to poke fun at the obstructionist, do-nothing, rule-bound Sir Humphreys that we are told dominated the public service in the 1960s and '70s, let us consider the detrimental consequences of moving policy formulation upwards to the ministerial level, which is implicit in the drive to make the public service more 'responsive'. Policy thereby becomes more vulnerable to the ebbs and flows of political life and the tabloid headlines, pressuring ministers to make policy on the run, making reflective policy analysis more challenging. Ministers are required to be in command of the content of their portfolios to a greater depth and with less preparation time than traditionally; and given complexity, it becomes easier to rely upon the advice of their closest advisors (political staffers) and those who have lobbied most recently. The scientific literacy of their closest confidantes assumes greater significance than under the traditional model. If that is lacking, scientific insight will understandably not feature prominently in the responses.

As policy-making migrates upwards, political sensitivity diffuses downwards to lower ranks of the service. Anecdotally, in the Queensland service it would appear that many mid-level officers nowadays feel obliged to apply a political filter to policy options going up the line, thus narrowing the advice offered.

Traditionally, the role of an elected member has been to represent their community. This required high-order skills in communication and an ability to make sensible judgements out of a large volume of proffered opinion from disparate sources against a background of political noise. Deep technical expertise was not required as parliamentarians relied upon the public service to sieve and translate technical knowledge from various specialists into policy-digestible format. The trend towards responsiveness within the public service now places very different responsibilities upon the shoulders of ministers: to form judgements about complex technical information themselves, directly and personally; and to defend them on the nightly news.

This role requires of policy-makers that they develop a coherent conceptual framework – a world view – capable of continually accommodating new information that might challenge existing orthodoxy. Scientific method is an essential element in forming and refining such a conceptual framework. The assumption-led discipline of economics and the faith-led ideology of conservative fundamentalism cannot match science in this function.

The contemporary minister is expected to be able to differentiate lobbying by self-interested business groups from lobbying by public interest supplicants such as scientific societies. This requires deep knowledge of every topic that crosses their desk, both as to technical detail and as to context.

Yet the capacity to digest technical information and inject it into policy is not part of the job description when a local branch of a political party pre-selects candidates for political office. At the entry level, candidates are chosen for their factional support, ideological outlook, communication skills and personability. However, it is from the pool of such candidates after they are elected that the ministry is chosen. The traditional method of selecting politicians has not caught up with the expectations of ministers under new managerialism.

CASE STUDY: LAND-USE PLANNING IN QUEENSLAND POST-1980

The fate of land-use planning during the past two-and-a-half decades offers an interesting case study in the deterioration of science-led policy capability within Queensland. 'Land-use planning' here refers to spatial land-use planning along with the mapping and natural resource (biophysical) assessment that is its essential precursor. It can be statutory or, as in NRM planning in Queensland, non-statutory.

In the Bjelke-Petersen era, the office of the then aptly-named Coordinator-General included strategic land-use planning. The office produced reports such as *Moreton Region Growth Strategy* (1976), a regional planning study that seems simplistic by the standards of modern regional plans, but at the time was a credible blueprint that aimed to shape development of greater Brisbane.

During the 1990s, the strategic planning function of the office of the Coordinator-General withered as the incumbent saw or was instructed to see his role as project facilitation, steering construction projects through bureaucratic obstacles, including environmental objections.

The policy-enthusiastic Goss administration in 1990 launched the SEQ 2001 initiative, an attempt to comprehensively plan for urban growth and development across the region. The reasons why this fizzled out in the mid-2010s remain to be chronicled, but the regional planning agenda was not helped by the passage in 1997 of developer-friendly performance-based planning legislation that did not envisage prohibition of development and was not accompanied by the funds essential to allow all departments to translate their scientific knowledge into spatial terms (mapping of constraints and opportunities, in other words) that planners could accommodate.

In 2009, a valiant attempt was made by SEQ Catchments, the non-statutory regional natural resource management body for South East Queensland, to format its NRM plan (State of Queensland 2009) so that it could be called up into the regional statutory plan as reference and policy material, a technique that following official endorsement would give the targets statutory teeth. This attempt did not reach its potential because of the demise of regional statutory planning during the Newman government era of 2012-15.

The present ministry has a big challenge to rebuild capacity lost during the years of the Newman government, when for example the unit responsible for much of the land-use planning in the non-urban Regional Landscape and Rural Production Area was abolished. Coordinating forums with non-government experts such as the long-standing Regional Landscape and Open Space Advisory Committee languished with no one in government seeming to be interested in its views or its status under the Regional Plan. It takes a decade or more for a bureau to recover expertise built up over a decade or more. The loss of this expertise is likely to cost the state dearly through the absence of a sieve to evaluate the most efficient localities for new urban development, or the merits of (and the best locations for) grand infrastructure projects.

UNSOLICITED PROPOSALS UNDERMINE PLANNING

Traditionally, the public service would conduct a thorough investigation into the biophysical attributes and social conditions of a study area, before compiling a regional, infrastructure, or local government planning scheme. These plans would be exposed to public consultation before being submitted for Cabinet approval. Project proposals would be generated from them.

In 2015, Queensland Treasury established a secretariat to fast-track what it euphemistically calls 'market-led proposals', being construction projects that a commercial company thinks can be profitable, but that the government has not previously considered. Such proposals, also termed 'unsolicited', bypass all of the planning procedures, including science-based natural resource assessment, that used to be regarded as essential precursors to project conception and instead grant to a private financier or construction firm a direct champion embedded inside Treasury. No amount of project-specific environmental impact assessment after an application has gained momentum can substitute for multi-lateral consultative land-use planning on a broader canvas, and in the early stages (Edwards 2016).

SEEDS OF SYSTEMIC FAILURE SOWN ON GOVERNMENT SIDE

Here we can see the seeds of systemic failure on the government side of the translation process. Given that the role of the public service as custodian of technical excellence has been eroded through

repeated restructuring, market-led outsourcing and downsizing, especially the downsizing of middle management (deemed 'non-frontline services') where does a non-expert minister turn for authoritative, independent technical advice? How can non-expert ministers differentiate solidly grounded science from ideologically distorted versions or self-interested interpretations by lobby groups?

It is a question of time as well as talent. Time is not on the minister's side to allow research and reflection. Ministers are under insane pressure with at least four full-time jobs: as a representative of the electorate, as a member of the party apparatus, as the leader of a portfolio department and as a member of whole-of-government Cabinet.

Few parliamentarians have been trained in scientific method. Only 9% of current national parliamentarians have been trained in a discipline related to science, technology, engineering, maths or medicine (Johnston 2016). (Contrast this with China's recent experience: Wikipedia records that eight out of the nine members of the 2007-2012 Politburo Standing Committee were scientists or engineers). Johnston identified four skills that scientists possess that could transform policy-making if widely shared:

- visioning (seeing patterns in data not immediately discernible to others);
- systems thinking (solving problems on the basis of analysis);
- adherence to structure (understanding of experimentation and testing); and
- collaboration (through experience in teamwork).

These elements of every scientist's training can be summarised by 'familiarity with scientific method', the ability to trace cause and effect. Science embraces a never-ending search for causation. Public policy must be grounded upon an understanding of the causative forces that have led to the current ills and the preconditions for successful remedies.

The traditional practice of embedding content-rich public servants in a minister's office on secondment can improve the office's technical capacity, but post-Whitlam, the primary staffers have more likely been selected from outside the public service for their skills in the arts of politics. The political staffers are necessarily focused on achieving political outcomes for their minister rather than the public good. The growth since the 1980s in the numbers of political staffers is both cause and effect of a decline in analytical capacity within the public service.

The minister will be well served if at least the senior departmental officers with whom the office engages routinely are in command of the technical complexity of the portfolio, but even this is not always the case. Then even if ministers are well fortified, they must deal in Cabinet and their party with colleagues who are sceptical or downright hostile for ideological or portfolio reasons.

In some portfolios, opportunities for ministers to be briefed by scientists might be infrequent. Scientists are rarely invited onto government boards such as Building Queensland, Infrastructure Australia or the Productivity Commission and are not funded to attend business dinners at which access to ministers can be purchased.

This line of reasoning leads to the conclusion that every minister needs effective coordinating forums that can coordinate technical knowledge so that evidence-based policy is not held hostage to over-simplifications from the tabloid press or unreceptive dynamics at the Cabinet table.

SEEDS OF SYSTEMIC FAILURE SOWN ON THE SCIENCE SIDE

The problems identified above are not solved by producing more scientific reports, necessary though they are for crystallising knowledge at a point in time and for reconciling disjointed hypotheses within scientific circles. The contemporary divergent attitudes by the Queensland Government and the Commonwealth Government towards the causes of, for example, coral bleaching reflect a broader, international culture war waged against climate science and won't be reconciled by more science.

The prevailing economics-focused mindset explains some of the gap. The environment is considered to be an 'externality' to the models of neoclassical economics that lie at the heart of the economic rationalist policy framework introduced to Australia from 1983. By definition, environmental public goods that are unpriced or only awkwardly priced in commercial markets cannot be modelled as contributors to economic activity. So they are implicitly regarded as impediments to economic activity. Conversely and perversely, commercial

firms are regarded as the source of economic prosperity, a fallacy nourished by using GDP (which does not tally value added by government activity) as the mainstream measure of economic success.

Bodies like CSIRO, the ABC and the Australian Conservation Foundation that are well placed to broker dialogue between scientists and government are themselves public goods that rely upon public funding. For this reason, it seems, they are victims of unrelenting hostility from the pro-market think tanks and neo-conservatives within parliament. The House of Representatives in 2015/16 even ran an enquiry into whether non-partisan organisations' tax deductibility should be withdrawn if they engage in policy advocacy (2016), therein conflating policy with politics.

It is depressingly difficult to envisage any feasible pathway for boosting the translation of science into policy on a broad scale, in Queensland or nationally, because this will require public good funding. Research scientists active in generating original data are obliged by chronic underfunding and by the performance measures imposed upon their sector to focus on producing scholarly papers and on educating students from other countries. Engaging with policy analysts and politicians is not part of their job description and would be an impediment to their research, even if they had the skills, training and aptitude.

Arguably, the onus for assembling evidence of our current environmental predicament and its origins and consequences lies upon individual scientists, scientific societies and the environment movement. However, the onus for restructuring our nation's policy apparatus to make it receptive, and for standing up to bullies in the media, unavoidably lies upon our representatives in the political arena.

SOME OPTIONS FOR REBUILDING SCIENTIFIC CAPACITY

There are many steps that a concerned Queensland government might take to rebuild its own capacity to incorporate scientific knowledge into its deliberative processes, some systemic and some simple and incremental.

The NRM bodies have long been loci of natural resource assessment, mapping, knowledge brokering and outreach. It would be very easy for the network of regional NRM bodies to scale up NRM planning on behalf of all levels of government, if given a mandate and a line of secure funding. However, this activity is only a subset of the functions necessary for statewide strategic planning and coordination.

There is a case for a new statutory entity to conduct some land-use assessment and planning activities on behalf of central government, but this would warrant another article.

In 2015, in response to external pressures, the Queensland Chief Scientist convened the Great Barrier Reef Water Science Task Force which in a substantial Final Report (May 2016) sought to coordinate scientific knowledge horizontally across portfolios and vertically between policy and implementation. The depth and breadth of expertise in the Taskforce and its Review Group suggest that the Office of the Chief Scientist might well be a congenial home for multi-lateral science-rich studies of the kind discussed here. However, to invest it with responsibility for spatial land-use planning would subordinate the urban design dimension of statutory planning to the environmental dimension, a bridge likely to be too far for Queensland's planning profession.

The Parliamentary Library has a research and reporting function in the service of members of Parliament from all parties. If it were given additional resources to strengthen its science capability, and if regular, well-structured briefings were scheduled for members, the Library could improve substantially the scientific literacy of the Parliament and reduce partisan rancour. It would also give access to real-time scientific information to backbenchers from all parties, who don't have routine access to the public service. There would be a risk, however, that any increased capability in the Parliamentary Library would be seen as a substitute for strengthened capability in the public service, which it can never replace.

There are many simple and inexpensive measures. By central directive, scientists could be appointed to all advisory committees and boards, to Treasury and to the Department of Premier and Cabinet. Knowledge of scientific method could be made a selection criterion for any aspirant to the senior executive service. The government or the Parliament could allow (and fund) learned societies to converse with parliamentarians in non-partisan information-

sharing forums [1]. The government could directly host or support learned societies in hosting professional development or refresher courses in scientific method for leaders in government and business who have not been educated in a scientific discipline.

CONCLUSIONS

The analysis above argues for establishing (or re-establishing) a capability in Queensland to translate scientific knowledge into policy and decision-making; and also to build knowledge of scientific method throughout the ranks of parliamentarians and the public service. There is no magic wand pathway to building such scientific capacity, but there are many possible partial measures not all requiring significant increases in funding or changes to the machinery of government.

However, any such measures will require acknowledgement by central government of the value of scientific capacity and the consequences of disregarding scientific evidence. Therein lies the self-reinforcing negative feedback with which our current institutions of governance are afflicted.

The coral bleaching mentioned at the head of this article is a warning that it is too late to avoid catastrophic destruction to the great biophysical systems on which human and planetary life depends. However, disruption will be episodic and at every locality will be of unpredictable scope and intensity. Our society will need much greater problem-solving expertise and much better brokering of scientific information if it is to navigate serviceable pathways through the problems that are now demanding policy and political attention.

DISCLAIMER

This address reflects the personal views of the author and not necessarily the views of the Council or members of the Royal Society of Queensland.

1 Note added in proof: The Royal Society of Queensland acknowledges with thanks a grant under the Engaging Science program from the office of Ms Leanne Enoch, Minister for Science and the Digital Economy, to present forums in 2017/2018 for this purpose. This is a refreshing counter to the pessimistic tone of the article.

LITERATURE CITED

ANON. 14 Oct 2016. Macquarie Island: Frydenberg announces $50m boost to research station. ABC AM program. Available at http://www.abc.net.au/news/2016-10-14/macquarie-island-frydenberg-announces-50-mill-boost/7931602 (accessed 12 November 2016).

AUSTRALIAN PUBLIC SERVICE COMMISSION. 2006. Supporting Ministers, Upholding the Values. (Canberra), p.11.

BURGESS, V. 5 Nov. 2004. Deliver — And No Excuses Taken. The Australian Financial Review. p.68.

CO-ORDINATOR GENERAL'S DEPARTMENT, QUEENSLAND AND CITIES COMMISSION. 1976. Moreton Region Growth Strategy. (Brisbane).

DAVIS, G. & WELLER, P. 1993. Strategic Management in the Public Sector: Managing the Coastal Zone. (Resource Assessment Commission. Canberra).

EDWARDS, G. 2014. Spanning Communication Circles. Wildlife Australia Spring 2014: 42-45.

EDWARDS, G. 2016. Transport Infrastructure Planning Has Lost Its Way. Research Report. (TJ Ryan Foundation. Brisbane).

HOUSE OF REPRESENTATIVES STANDING COMMITTEE ON THE ENVIRONMENT. April 2016. Inquiry into the Register of Environmental Organisations. (Canberra).

JOHNSTON, E. 18 Oct. 2016. We need more scientists to take the leap into politics. The Sydney Morning Herald. Available at http://www.smh.com.au/comment/we-need-to-see-more-scientists-take-the-leap-into-politics-20161017-gs3u5z.html (accessed 12 November 2016).

JONES, C. 8-14 Oct. 2016. Unhealthy climate. The Saturday Paper. (Melbourne).

KEATING, M. Mar. 1999. The Public Service: Independence, Responsibility and Responsiveness. Aust. J. Pub. Admin. 58(1):39-47.

MANNING, P. 6 June 2016. A hidden agenda? Larry Marshall and the CSIRO's climate scientists. ABC Radio. Available at http://www.abc.net.au/radionational/programs/backgroundbriefing/a-hidden-agenda-larry-marshall-and-the-csiro-climate-scientists/7480370 (accessed 12 November 2016).

MCCUTCHEON, P. 28 Mar. 2016. Great Barrier Reef coral bleaching at 95 per cent in northern section, aerial survey reveals. ABC News. Available at http://www.abc.net.au/news/2016-03-28/great-barrier-reef-coral-bleaching-95-per-cent-

north-section/7279338?pfm=ms (accessed 12 November 2016).

PARKINSON, M. Oct. 2016. Think again — the changing nature of policy implementation. The Mandarin blogsite. Available at http://www.themandarin.com.au/71267-martin-parkinson-think-changing-nature-policy-implementation/# (accessed 9 Oct. 2016).

READFERN, G. 10 June 2016. A misrepresentation of science. DeSmog Blog. Republished by Independent Australia. Available at https://independentaustralia.net/environment/environment-display/the-australians-great-barrier-reef-editorial-amisrepresention-of-science,9093 (accessed 12 November 2016).

STATE OF QUEENSLAND [Department of Environment and Resource Management]. 2009. South East Queensland Natural Resource Management Plan (2009-2031). (Brisbane).

AUTHOR PROFILE

Dr Geoff Edwards B.Sc.(Hons.); M.Pub.Ad.; PhD; GAICD is qualified in ecological science and public policy. He worked in parks and Crown land administration in Victoria and Papua New Guinea. He was a local government Councillor for six years and Shire President in Victoria. From 1991-2006 he served in Queensland's Department of Lands/Natural Resources as Manager, Land and Regional Planning, with responsibilities for a range of aspects of land policy. After a stint in 2007-8 as Chief Executive Officer of South West NRM Ltd based in Charleville, he retired from the Department of Mines and Energy in 2011 having engaged in policy analysis regarding coal seam gas and oil shale. In June 2013 he was elected as President of The Royal Society of Queensland.

ANNUAL PATTERN OF SETTLEMENT OF SYDNEY ROCK OYSTER (*SACCOSTREA GLOMERATA*) SPAT IN PUMICESTONE PASSAGE, MORETON BAY

DIGGLES, B.K.

Natural spatfall of Sydney rock oysters (*Saccostrea glomerata*) was examined on shell cultch and three dimensional concrete spat collection units placed subtidally and intertidally in Pumicestone Passage, northern Moreton Bay. Spatfall of *S. glomerata* peaked in January and was detected in all months when water temperatures exceeded 24°C, which was consistent with historic data from Ningi Creek. The vast majority (93.77%) of *S. glomerata* spat that settled on concrete spat collection units recruited to internal or inverted surfaces that were shielded from silt. The highest numbers of recruited spat and invertebrates were detected subtidally on cleaned oyster shell cultch, which was on a weight for weight (or volume for volume) basis 10-90 (5-42) times more effective for attracting spat and 28-135 (13-62) times more effective for attracting invertebrates than concrete spat collection units. Monthly pressure cleaning of concrete collectors to remove silt deposits and algal turfs increased *S. glomerata* spatfall on the vertical sides of collection units, particularly on intertidal units, as well as encouraged settlement of other bivalves including *Pinctada albina*, *P. maculata* and *Hyotissa imbricata*, while *Trichomya hirsuta* occasionally settled on marker ropes. Increased mortality rates of *S. glomerata* spat on subtidal collectors during February and March was likely due to predation, however mortalities of older spat settled on both intertidal and subtidal units during the autumn and winter months may have been due to other causes, which may include QX disease, smothering due to blooms of cyanobacteria *Lyngbya* sp., brown algae *Ectocarpus fasciculatus* and/or jellyfish *Catostylus mosaicus*. These results confirm that *S. glomerata* spat can successfully recruit to shell cultch and concrete substrates in subtidal areas of Pumicestone Passage, suggesting that restoration of subtidal shellfish reefs in the area is feasible if appropriate settlement substrates are provided.

Keywords: MPA, oyster, shellfish, restoration, water quality, recruitment

INTRODUCTION

Oysters, mussels and other reef forming shellfish are important ecosystem engineers in estuaries, providing hard subtidal and intertidal reef structure, food and habitat for fishes and invertebrates, as well as services such as filtration of phytoplankton, nutrient uptake and fixation, benthopelagic coupling and shoreline stabilization (Newell 2004; Grabowski & Peterson 2007; Beck et al. 2011; zu Ermgassen et al. 2012, 2016). However, the extent of natural shellfish reefs and beds declined dramatically worldwide throughout the 19th and 20th centuries due to a suite of anthropogenic impacts that adversely affect estuaries and inshore marine ecosystems (Kirby & Miller 2005; Beck et al. 2011).

In Australia, shellfish reefs were formerly abundant in most estuaries along the southern and eastern coastlines prior to European settlement (Gilles et al. 2015a,b), but today they are classified as functionally extinct (Beck et al. 2011) and in many locations their historical presence has been erased from human memory (Alleway & Connell 2015). "Generational amnesia" leading to lack of recognition of lost shellfish reefs represents a significantly shifted baseline for management of estuarine and coastal ecosystems in Australia (Diggles 2013; Alleway & Connell 2015; Gilles et al. 2015a,b), prompting realisation of the urgent need to undertake their restoration (Creighton et al. 2015; Gilles et al. 2015a).

Pumicestone Passage is the largest estuary in northern Moreton Bay in south-east Queensland, Australia (Figure 1). Shellfish resources in Moreton Bay were utilized for thousands of years by indigenous groups (Diggles 2015); however, since European settlement shellfish were exploited for food and Aboriginal shell middens were also raided to make lime to build roads and buildings (Smith 1981; 1985). The Moreton Bay oyster industry mainly utilised Sydney rock oysters (*Saccostrea glomerata*), an important reef forming species which was historically exploited on intertidal banks as well as by dredging subtidal shellfish reefs (Saville-Kent 1891; Smith 1981). Industry production peaked in 1891; however, landings subsequently declined to less than 10% of the peak (Smith 1985) due to damage from dredging, sedimentation and declining water quality brought about by development

in the catchment (Diggles 2013). In Pumicestone Passage historical records show abundant subtidal and intertidal shellfish reefs occurred in the mid to late 1800s (Saville-Kent 1891), but today around 96% of zonation suitable for natural *S. glomerata* recruitment (recruitment being defined as successful settlement, survival and growth of planktonic spat into juvenile oysters) has been lost and subtidal shellfish reefs are functionally extinct (Diggles 2013).

In contrast to the prolific recruitment of *S. glomerata* spat in Pumicestone Passage over 120 years ago (Saville-Kent 1891), today successful natural spat recruitment is disrupted below approximately 1.1 metres above low water datum (Diggles 2013). Studies in the late 1970's found natural *S. glomerata* spat recruitment at Ningi Creek in Pumicestone Passage occurred from November to April, peaking in December with spatfall generally heavier in the lower part of the tidal range (Potter 1984). The current lack of successful natural spat recruitment below 1.1 meters above low water datum may therefore be a relatively recent phenomena, thought to be due to lack of suitable settlement surfaces for oyster larvae as constantly resuspended sediments (Morelli et al. 2012) lodge in algal biofilms stimulated by eutrophication (McEwan et al. 1998), interfering with settlement cues and resulting in spatfall failure. In view of the desire of traditional owners and the local community to begin restoration of shellfish reefs in Pumicestone Passage (Diggles 2015), the present study was undertaken to determine if the timing of peak natural *S. glomerata* spatfall in the area has changed since the late 1970's (Potter 1984), and to compare spatfall in intertidal vs subtidal areas, to determine whether natural spatfall could be used for reef restoration in subtidal areas if suitable restoration substrates were provided.

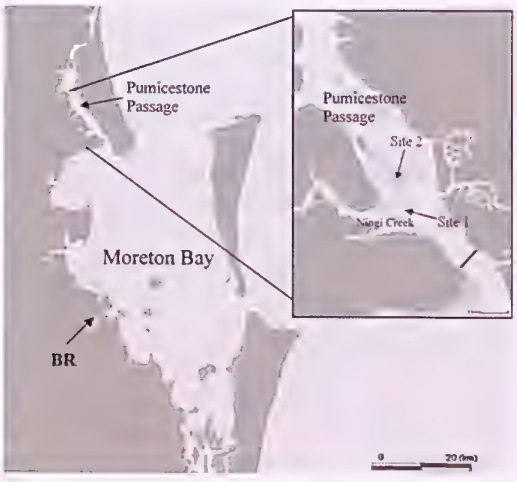


FIG. 1. Map showing location of experimental sites in Pumicestone Passage, northern Moreton Bay. BR = Brisbane River.

METHODS

Natural spatfall of mainly Sydney rock oysters (*Saccostrea glomerata*), but also opportunistic observation of spatfall of several other shellfish species including hairy mussels (*Trichomya hirsuta*), pearl oysters (*Pinctada albina albina*) and saddle shaped oysters (*Hyotissa imbricata*), was examined every month in Pumicestone Passage, northern Moreton Bay for a period of 15 months. Experiments were conducted using artificial three-dimensional concrete spat collection units, concrete oyster reef balls and *Saccostrea glomerata* shells (natural shell cultch) placed on intertidal banks and in subtidal channels at two sites from September 2015 to November 2016.

Site 1 (27°03.504 S, 153°07.349 E) was located on the northern side of the mouth of Ningi Creek (Figure 1). Here the intertidal units were placed approximately 1 metre above low water datum, with subtidal units deployed at around 0.5 metres below low water datum on a mixed sand/mud substratum. Site 2 (27°02.834 S, 153°07.155 E) was located on the western bank of Neds Gutter (Figure 1), where the intertidal units were placed approximately 1 metre above low water datum with subtidal units deployed at around 0.6 metres below low water datum on a natural dead *S. glomerata* shell/mud substrate. Subtidal units deployed at both sites were loosely linked together with 6 mm polypropylene marker rope to facilitate their retrieval.

ARTIFICIAL THREE DIMENSIONAL SPAT SETTLEMENT UNITS

The artificial three-dimensional spat collection units used at both sites were standard concrete Hanson (Besser™) blocks, 13.9 kg in weight, 39 x 19 x 19 cm (LxWxH) in dimension, with 2 internal cavities 14.5 x 19 x 12.5 cm (LxWxH) in dimension (Figure 2). The design of these blocks provided a volume of 14,079 cm^3, a horizontal upper and internal settlement area of 1292 cm^2, a similar area of inverted/internal settlement area, and vertical settlement areas of 1672 cm^2 per unit (Figure 2). Three settlement units were placed subtidally and 3 intertidally at each

site (Supplement Figure 1). To provide a measure of monthly spatfall rates, one subtidal unit and one intertidal unit from each site was removed from the water and replaced with a new unit at monthly intervals (replace treatment). One other intertidal and subtidal unit from each site was pressure washed (clean treatment) each month and replaced after counting spatfall prior to washing, while the third remaining intertidal and subtidal unit at each site was monitored for spatfall only (monitor treatment) and otherwise remained undisturbed for the duration of the experiment. Differences in spat recruitment and survival between subtidal and intertidal areas were examined by averaging data for each treatment (monitor, clean, replace) between both sites.

SETTLEMENT ON NATURAL SHELL CULTCH

A polyvinyl chloride (PVC) oyster tray 60 x 40 x 7 cm (LxWxH), containing 100 cleaned and dried *S. glomerata* shells (2.3 kg total weight, 5,000 cm^3 volume) was tied to the top of a single Hanson block (which acted as ballast and elevated shells away from benthic sediment, Sawusdee et al. 2015), and placed subtidally (n = 1) and intertidally (n = 1) at each site (total n = 4 trays) for 30 days every second month (shell cultch treatment, see Supplement Figure 1). At the end of each 30 day period the units were retrieved and the shells were emptied from the trays into a 20 L bucket of seawater to keep them wet until each oyster shell could be visually examined for *S. glomerata* spatfall and the presence of invertebrates or fishes (see section on counting of settled spat, fishes and invertebrates). Data were then averaged between both sites to examine for differences in spatfall between subtidal and intertidal areas.

SETTLEMENT ON OYSTER REEF BALLS

An additional two hollow concrete, conical-shaped oyster reef balls (Reefball Australia Ltd., 35 cm height x 45 cm base diameter with an 18 cm hole through the top) were placed subtidally at each site (Supplement Figure 1). The outer surface of one of the reef balls at each site was pressure washed (clean reef ball treatment) each month after counting spatfall prior to washing, while the second reef ball at each site was monitored for spatfall only (monitor reef ball treatment). After completion of counting and cleaning, each reef ball was returned to its original

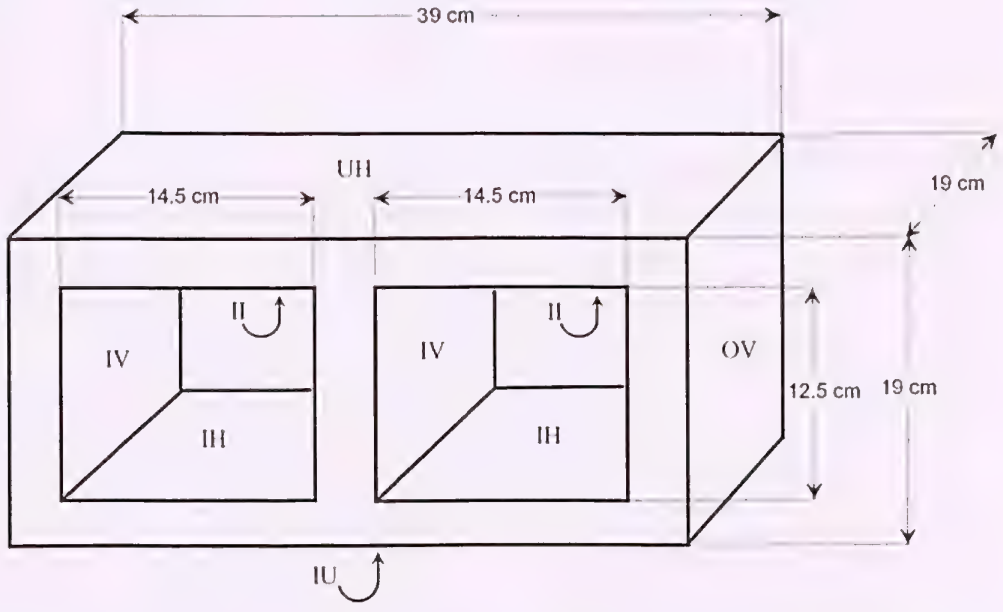


FIG. 2. Dimensions and nomenclature for three-dimensional concrete spat collection units (Besser blocks). UH = upper horizontal surface, IH = internal horizontal surfaces, IV = internal vertical surfaces, OV = outer vertical surfaces, IU = inverted under surface, II = inverted internal surfaces.

subtidal location. Data for each treatment (monitored or cleaned) were then averaged between both sites and compared to examine whether regular cleaning made a difference to spat recruitment and/or survival.

COUNTING OF SETTLED SPAT, FISHES AND INVERTEBRATES

Each month from end of September 2015 to end of November 2016 during low water spring tides, I visually recorded the number of *S. glomerata*, other shellfish spat, fishes and invertebrates recruiting to each three dimensional concrete settlement unit and the oyster reef balls from the previous 30 days' deployment. The relative settlement position of each spat recruiting on the three dimensional settlement units (i.e. upper, vertical, internal and inverted under surfaces) was noted using nomenclature shown in Figure 2. Intertidal units in the monitor treatment were inspected *in-situ*, while subtidal units in the monitor and clean treatments were retrieved onto the intertidal bank during the counting and cleaning process for no more than 30 minutes each month before being replaced subtidally after monitoring was completed. Spatfall and counts of invertebrates on settlement units in the clean treatment were done prior to pressure cleaning. The presence of other associates when they occurred, particularly fishes, was also noted prior to retrieving or inspecting each unit. On 4 occasions (February, April, June and August) an underwater camera (GoPro™) was deployed near the reef units for between 1 to 2 hours to visualise and record behaviour of fishes and invertebrates associating with the units. The pressure cleaning process for units in the clean treatment was undertaken every 30 days using saltwater obtained on-site and pressurised using a gasoline powered self priming high pressure washer (Black Eagle model number AGT-BE80). During cleaning the blasting nozzle was held 30-50 cm from the surface of the settlement units or reef balls being cleaned, so the pressure spray was sufficient to remove sediment and algal overgrowth without removing settled shellfish spat.

Spat and invertebrates which settled on the natural shell cultch were counted by removing the shell cultch from the oyster tray and placing it into a 20 L bucket of seawater taken from the site. The bucket of shells was then taken back to the laboratory where any spat, invertebrates and fish eggs which had settled on each shell were inspected visually, counted and representative taxa identified under a dissecting microscope when necessary. Data were then averaged between both sites to examine for differences in spatfall between subtidal and intertidal areas.

LOSS OF SOME EXPERIMENTAL UNITS

Unauthorised removal and theft of the intertidal natural shell cultch trays at sites 1 and 2 in October and November 2015 lead to subsequent utilisation of a single subtidal natural shell cultch unit at each site, deployed for 30 days every second month from December 2015 to November 2016. Unauthorised removal and theft of two of the subtidal reef balls from site 1 in October 2015 meant that data for subtidal reefballs could be obtained only from site 2 for the remaining 12 months from November 2015 to November 2016.

WATER QUALITY MEASUREMENTS

Basic water quality parameters including temperature, salinity, turbidity and dissolved oxygen were measured each month at both sites. Water temperature (°C) and dissolved oxygen (DO in mg/L and % saturation) were measured using a YSI 85 multimeter with a 30 meter probe cable, salinity (‰) was measured with the YSI 85 multimeter and a calibrated refractive salinometer, while turbidity was measured with a 20 cm diameter secchi disk and a turbidity tube (Westlab Pty Ltd.). The presence of blooms of algae and jellyfish that potentially affected the experimental units was also noted when they occurred.

RESULTS

WATER QUALITY

Basic water quality parameters measured over the duration of the experiment are presented in Supplement Table 1. Water temperature ranged from a high of 27.4°C at site 1 in December 2015 to a low of 15.4°C at site 1 in June 2016. Salinity ranged between 32 and 37.6‰, decreasing from the typical 35-36 ‰ only following occasional heavy rains in the days leading up to sampling in October 2015, April 2016, and June 2016. Dissolved oxygen varied from a low of 4.68 mg/L (75% saturation) at site 1 in November 2015 to a high of 8.5 mg/L (117% saturation) at site 1 in May 2016. Turbidity was variable with secchi depths ranging between 1.3 metres (approximately 12 NTU) and 2.5 meters (<9 NTU) with a trend towards reduced turbidity during the late winter months (Supplement Table 1). This may be due to the fact that turbidity was directly related to rainfall and wind strength due to wave resuspension of sediment over shallow banks during periods where wind exceeded 12-

Table 1. Data on settlement microhabitats utilised by *S. glomerata* spat collected on various surfaces of three dimensional concrete spat collection units (see Figure 1 for nomenclature). The vast majority (93.77%) of spat settled on the inverted and internal surfaces of the spat collection units, while regular pressure cleaning increased the number of spat settling on outer vertical surfaces in intertidal areas. Numbers indicate number of spat settlement observations.

Treatment	Subtidal			Intertidal		
	Top (UH)	Sides (OV)	Under/internal (IU, II, IV, IH)	Top (UH)	Sides (OV)	Under/internal (IU, II, IV, IH)
Monitor	0	37	777	0	35	725
Clean	1	11	630	2	197	1750
Replace	1	8	487	0	16	269
Total	2	56	1894	2	248	2744

15 knots (B.K. Diggles, personal observations). Due to the relatively shallow depth of the water at both sites (maximum depth approximately 3 metres over subtidal units at high tide), the water column was well mixed and no differences in water temperature, salinity and DO between the water surface and the bottom were noted.

Two algal blooms of magnitude judged sufficient to cause a smothering risk to the experimental units were observed during the course of the experiment. The first bloom was caused by the toxic cyanobacterium *Lyngbya* sp. (known locally as fireweed) which was noticed in small (15-20 cm) clumps attached to experimental units and marker ropes at both sites in April 2016, increasing in extent by June 2016 then becoming less evident for several months during the *Ectocarpus* bloom (see below) until intensifying into a heavy bloom involving numerous drifts between 30 and 60 cm long by November 2016, at which time the experiment was terminated. The second and more intense bloom was caused by the brown algae *Ectocarpus fasciculatus* (locally known as snotweed) that bloomed into large drifts 1-1.5 metres long that collected on marker ropes and covered spat collection units in August and September 2016 at both sites, but particularly at site 1 where a high risk of smothering of experimental units was noted (Supplement Figure 2). The late winter/early spring *Ectocarpus* bloom coincided with the increase in water temperature from winter lows during a period before turbidity increased due to summer wind and rainfall patterns (Supplement Table 1).

An unusually intense bloom of the blue blubber jellyfish *Catostylus mosaicus* was also observed in October 2016, continuing to increase in intensity into November 2016 to densities estimated to peak around 5-7 individuals/ m^3 in locations near the mouth of Ningi Creek at site 1. These large (20-25 cm bell diameter) jellyfish were observed to lodge against experimental units located in intertidal areas at both sites, representing a smothering hazard. At the end of the experiment in November 2016 the upper horizontal (UH, see Figure 2) surfaces of subtidal experimental units at site 1 became colonised by dense clumps of the brown algae *Padina australis*; however these did not appear to represent a smothering hazard due to the absence of settlement of *S. glomerata* spat on the UH surfaces (see below).

SETTLEMENT ON 3 DIMENSIONAL SPAT SETTLEMENT UNITS

Settlement of *S. glomerata* spat was observed on both intertidal and subtidal spat collection units, but only in months where water temperatures exceeded 24°C (Figure 3). Peak spat settlement was recorded in January 2016 on subtidal units when an average of 108.5 spat/ unit was recorded (Figures 3, 4). More spatfall was recorded on subtidal units during late spring and early summer (Figures 3, 4), but cumulative survival of spat over several months into autumn and winter was highest on intertidal units (Figure 5, Supplement Figures 3, 4), No spionid mudworm infestations were noted on any settled oysters (live or dead) at any time throughout the experiment.

Recruitment and cumulative survival of spat was higher on cleaned spat collection units placed in intertidal areas compared to those that were only monitored (Figure 5, Supplement Figure 4). However, for units placed subtidally, those that were monitored had lower initial spat recruitment, but higher cumulative spat survival compared to units that were pressure cleaned every 30

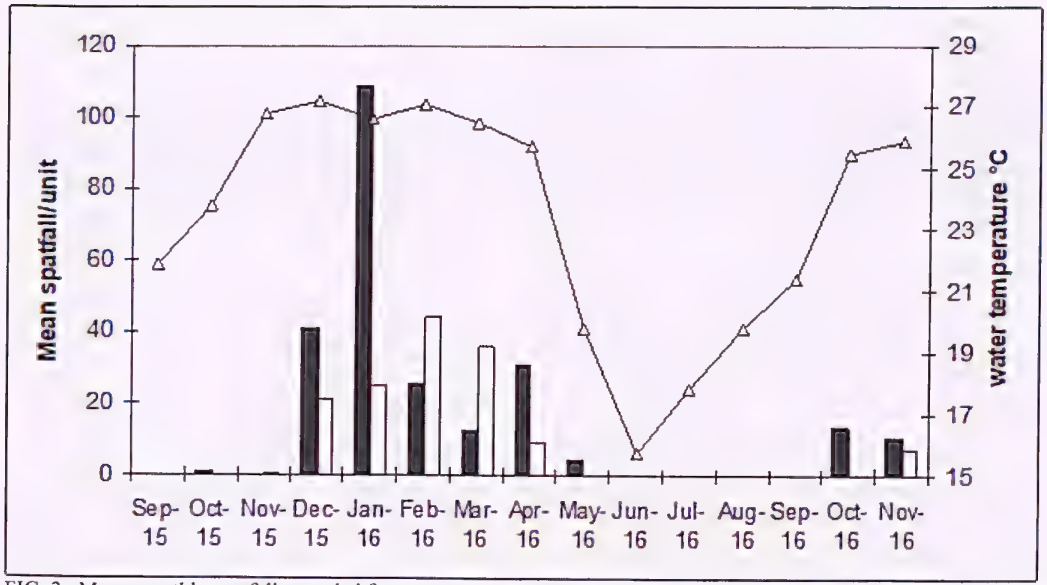


FIG. 3. Mean monthly spatfall recorded from concrete spat settlement units deployed and replaced at monthly intervals at 2 sites in Pumicestone Passage between September 2015 and November 2016 (Replace treatment). Spatfall was recorded on both subtidal (black columns) and intertidal (white columns) units whenever water temperature (-△-) exceeded 24°C. Peak spatfall was on subtidal units in January 2016.

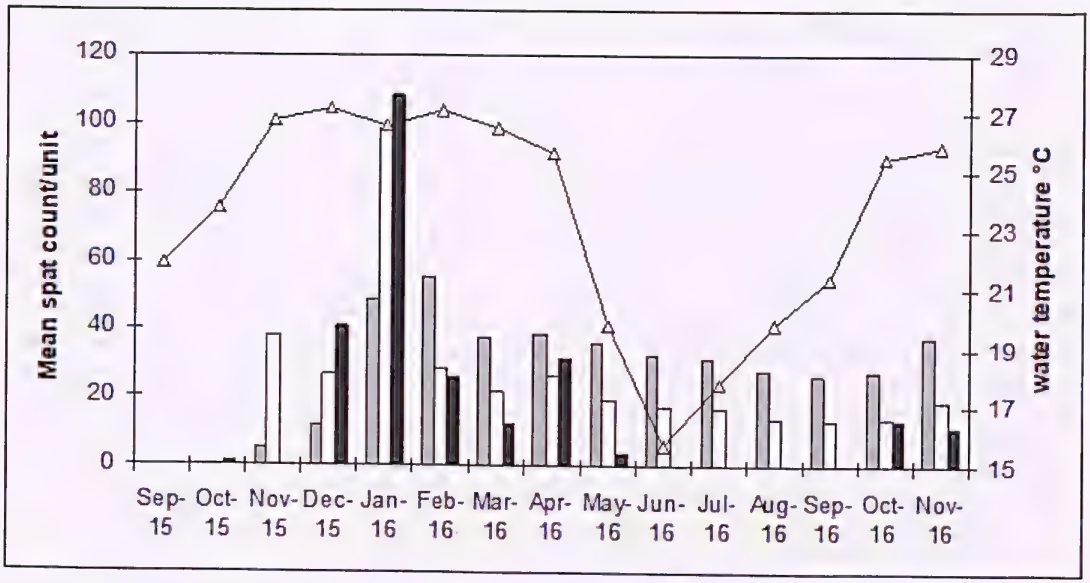


FIG. 4. Cumulative spatfall recorded from concrete spat settlement units deployed subtidally at 2 sites in Pumicestone Passage between September 2015 and November 2016 Units that were monitored only (Monitor treatment, grey columns) had lower spat recruitment, but higher cumulative spat survival compared to units that were pressure cleaned every 30 days (Clean treatment, white columns). Units that were replaced each month (Replace treatment, black columns) show when recruitment occurred. -△- water temperature.

days (Figure 4). When the microhabitats utilised by settled spat were investigated, only 4 out of 4946 spat settlement observations (0.081% of the overall total) were recorded on the upper horizontal surfaces (UH, see Figure 2) of the spat collection units, with all 4 of these being recorded on units that were either pressure cleaned or replaced every 30 days (Table 1). Only 304 spat settlement observations (6.1% of the overall total) were recorded for the outside vertical surfaces of the spat collection units (OV surfaces, see Figure 2), mostly on intertidal units that were subjected to regular pressure cleaning (Table 1). The remaining 4638 spat settlement observations (93.77%) were recorded from the inverted and internal surfaces of the spat collection units including surfaces IU, IH, IV, II (Figure 2).

Monthly pressure cleaning also encouraged settlement of small numbers of other bivalves on the sides of subtidal units including *Pinctada albina* and *P. maculata* (n = 6 observations at site 2 starting from March) and *Hyotissa imbricata* (n = 83 observations starting at site 1 in May and increasing at both sites 1 and particularly site 2 until August), while small numbers of hairy mussel (*Trichomya hirsuta*) spat (n = 39 observations) were observed to settle on marker ropes of subtidal units at site 1 in January.

SETTLEMENT ON OYSTER REEF BALLS

Patterns of spat settlement on the subtidal oyster reef balls at site 2 were similar to those observed on the three dimensional spat collection units, with the vast majority (91.6%) of the 1846 *S. glomerata* spat settlement observations being recorded from the inverted base or inside of the reef balls on surfaces that were protected from silt. The remainder (n = 155, or 8.4%) of *S. glomerata* spat observed settled on the sloped outer sides of the reef balls, mostly on the reef balls that were pressure cleaned every 30 days (n = 96 spat observations) compared to the reef balls that were monitored only (n = 59 spat observations). Again, monthly pressure cleaning encouraged settlement of small numbers of other bivalves on the outside of the reef balls including *Pinctada albina* and *P. maculata* (n = 44 observations, starting from March) and *Hyotissa imbricata* (n = 179 observations, starting from August).

SETTLEMENT ON NATURAL SHELL CULTCH

Unauthorised removal of the intertidal natural shell cultch trays at sites 1 and 2 in October and November 2015, respectively, prevented spatfall comparisons between intertidal vs subtidal shell cultch. However, spatfall data were available from natural shell cultch

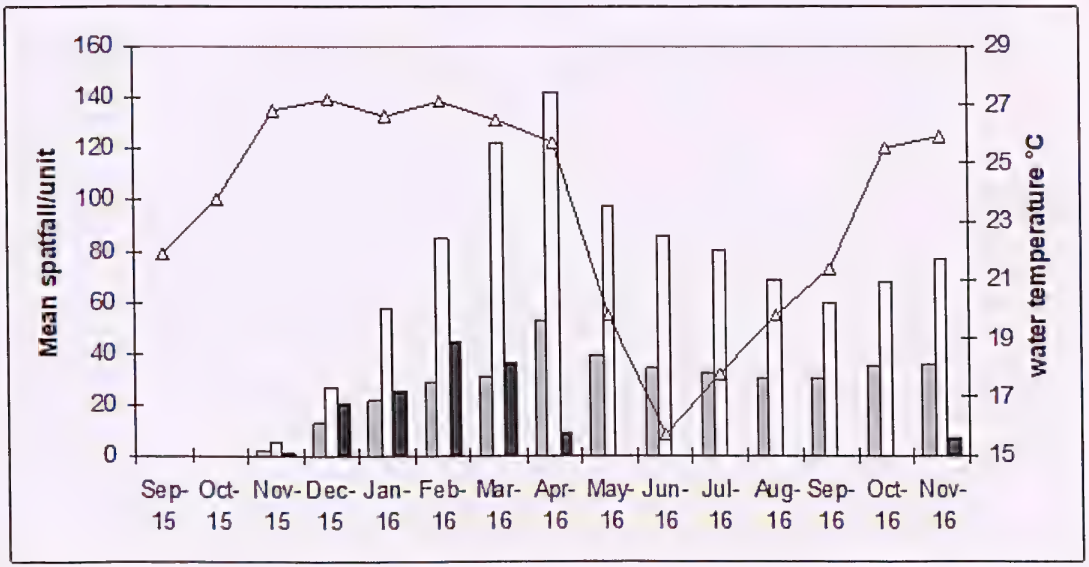


FIG. 5. Cumulative spatfall recorded from concrete spat settlement units deployed intertidally at 2 sites in Pumicestone Passage between September 2015 and November 2016 Units that were monitored only (Monitor treatment, grey columns) had lower spat recruitment, and much lower cumulative spat survival compared to units that were pressure cleaned every 30 days (Clean treatment, white columns). Units that were replaced each month (Replace treatment, black columns) show when recruitment occurred. -△- water temperature.

Table 2. Relative effectiveness of shell cultch vs three dimensional concrete spat collection units on a per weight and per volume basis for attracting settled *S. glomerata* spat at two subtidal sites in Pumicestone Passage. Data from 2.3 kg (5 litres) of oyster shells and 13.9 kg (14.079 litres) of concrete blocks each placed at 2 sites and replaced at 30 day intervals. - = data not available for that month.

Substrate		Dec 2015	Jan 2016	Feb 2016	Mar 2016	Apr 2016	May 2016	Jun 2016
Shell cultch	Total spat counted	144	-	768	-	276	-	0
	Spat/kg	31.3	-	166.9	-	60	-	0
	Spat/L	14.4	-	76.8	-	27.6	-	0
Concrete blocks	Total spat counted	82	217	51	25	62	8	0
	Spat/kg	2.95	7.80	1.83	0.9	2.23	0.29	0
	Spat/L	2.91	7.70	1.81	0.89	2.20	0.28	0
Relative effectiveness of shell cultch	per kg	10.6 :1	-	91.2 :1	-	26.9 :1	-	1 : 1
	per L	4.9 :1	-	42.4 :1	-	12.5 :1	-	1 : 1

Table 3. Relative effectiveness of shell cultch vs three dimensional concrete concrete spat collection units on a per weight and per volume basis for attracting invertebrates at two subtidal sites in Pumicestone Passage. Data from 2.3 kg (5 litres) of oyster shells and 13.9 kg (14.079 litres) of concrete blocks each placed at 2 sites and replaced at 30 day intervals. - = data not available for that month.

Substrate	Subtidal units at 2 sites	Dec 2015	Jan 2016	Feb 2016	Mar 2016	Apr 2016	May 2016	Jun 2016
Shell cultch	Total invertebrates	112	-	280	-	367	-	49
	Invertebrates /kg	24.3	-	60.9	-	79.8	-	10.7
	Invertebrates / L	11.2	-	28	-	36.7	-	4.9
Concrete blocks	Total invertebrates	5	61	60	29	22	10	4
	Invertebrates /kg	0.18	2.19	2.16	1.04	0.79	0.36	0.14
	Invertebrates / L	0.18	2.16	2.13	1.03	0.78	0.35	0.14
Relative effectiveness of shell cultch	per kg	135 :1	-	28.2 :1	-	101 : 1	-	76.4 : 1
	per L	62.2 :1	-	13.2 :1	-	47 : 1	-	35 : 1

placed subtidally every second month at both sites from October 2015 (total = 4.6 kg or 10 litres of shell cultch deployed each month). A total of 1875 spat were collected from oyster shell cultch, the PVC oyster trays and the single Hanson blocks used as ballast. The majority (n = 1207, or 64.4% of all spat) were collected from the natural shell cultch, while 217 spat (11.6%) were collected from the Hanson blocks and 451 spat (24%) settled on the undersides of the PVC oyster tray itself. The vast majority of the spat collected from natural shell cultch were recorded in December 2015 (n = 144, mean 31.3 spat/kg shell or 14.4 spat/L shell), February 2016 (n = 768, mean 166.9 spat/kg shell or 76.8 spat/L shell) and April 2016 (n = 276, mean 60 spat/kg shell or 27.6 spat/L shell) (Table 2). The effectiveness of subtidal shell cultch for attracting spat was a minimum of 10 times and maximum of 91 times more effective than concrete blocks when compared on a weight for weight basis, and around 5 to 42 times more effective when compared volumetrically (Table 2). Similarly, the peak effectiveness of subtidal shell cultch for attracting spat (166.9 spat/kg (76.8 spat/L) in February 2016, Table 2) was over 21 times that of the peak effectiveness recorded from the concrete blocks placed subtidally (mean 108.5 spat/ 13.9 kg block = 7.8 spat/kg (7.7 spat/L) in January 2016, Figure 3). Also notable during December, February and April was the collection of large numbers of crustaceans and other invertebrates of various species (Tables 3, 4) that recruited to shell cultch during these summer and early autumn deployments. Again, the natural shell cultch was far superior for attracting invertebrates, being 28 to 135 times (mean 85 times) more effective than the concrete blocks when considered on a weight for weight basis and 13 to 62 times (mean 39.3 times) more effective on a volume for volume basis (Table 3). Seasonal deposition of adhesive eggs by crested oyster gobies (*Cryptocentroides gobioides*) was also noted on the inside of oyster shells deployed at both sites during October 2015 and October 2016 (Figure 6).

INVERTEBRATES AND FISH

Over 40 species of fish and invertebrates were observed to be directly associated with oyster shells placed in the natural shell cultch trays and/or the three dimensional concrete spat settlement units (Table 4). The fishes most commonly associated with oyster shells inside shell cultch trays included juvenile and adult *C. gobioides* and juvenile (30-50 mm TL) parrotfishes (*Scarus ghobban*), while visual observations when retrieving subtidal units, and GoPro footage revealed at least 12 other species of larger fish to be closely associated with (either inhabiting or swimming adjacent to) the three dimensional spat settlement units or reef balls. The most common species included moses perch (*Lutjanus russelli*), yellowfin bream (*Acanthopagrus australis*), Bengal sergeant (*Abudefduf bengalensis*), tarwhine (*Rhabdosargus sarba*), and silver biddy (*Gerres subfasciatus*) which were visually observed when retrieving subtidal units throughout all months (Table 4). The main types of motile invertebrates observed included crustaceans such as portunid crabs (*Scylla serrata*, *Thalamita crenata*, *Charybdis* sp.), and other crab species from the Families Porcellanidae, Diogenidae and Xanthidae, as well as prawns (Family Penaeidae) and shrimp (Family Palaemoninae) (Table 4). The molluscs observed included several species of bivalves (*Saccostrea glomerata*, *Hyotissa imbricata Trichomya hirsuta*, *Pinctada albina*, *Pinctada maculata*), as well as motile gastropods such as mud whelks, snails, and oyster borers (Table 4). While not specifically noted each month, many species of coralline and encrusting algae, and colonial tunicates (*Symplegma* sp., *Botrylloides* sp.) were also evident on underside surfaces of experimental units placed in subtidal areas, particularly the II (inverted internal) and IV (inverted vertical) surfaces (Figure 2, Supplement Figure 5). No spionid mudworm infestations were noted on any settled oysters (live or dead) from any treatment at any time throughout the entire experiment.

DISCUSSION

It is inferred from study of the intertidal oyster banks in Pumicestone Passage that successful natural spat settlement of *S. glomerata* is currently disrupted below approximately 1.1 metres above low water datum (Diggles 2013). However, the results of the present study confirm that *S. glomerata* spat are still available for settlement below 1.1 metres above low water datum, and indeed spatfall and natural recruitment of *S. glomerata* spat was recorded up to 0.6 metres below the low tide mark in this study, whenever water temperatures exceeded 24°C (Figure 3). When the pattern of recruitment of *S. glomerata* spat onto three dimensional spat settlement units was examined, it was evident that around 94% of successful recruitment occurs on the inverted and internal vertical surfaces of the spat collection units, i.e. surfaces that were protected from silt (Table 1, Supplement Figure 5). It was evident that even when

spat settlement units were replaced with new ones every month (replace treatment), rapid accumulation of between 3-8 mm of silt/month onto the upper surfaces of the units prevented successful spatfall onto these surfaces (less than 0.1% of recruitment). Regular (monthly) pressure cleaning of the outer surfaces of three dimensional spat settlement units and reef balls to remove sediment and algal turfs slightly improved spatfall onto the vertical surfaces (Table 1), but not the horizontal surfaces, demonstrating that gravity-induced settlement of silt is less problematic on vertical surfaces where only thin layers of silt can be retained on algal biofilms. These data suggest that failure of successful natural spat settlement of *S. glomerata* in Pumicestone Passage below approximately 1.1 metres above low water datum is due to a lack of availability of suitably clean hard settlement surfaces as constantly resuspended fine sediments (Morelli et al. 2012) blanket virtually all horizontal surfaces and lodge in algal biofilms colonising vertical surfaces, interfering with spat settlement cues (as hypothesized by Diggles 2013).

The period of spat settlement observed in the present study occurred over a slightly longer time period than recorded by Potter (1984), who found recruitment at

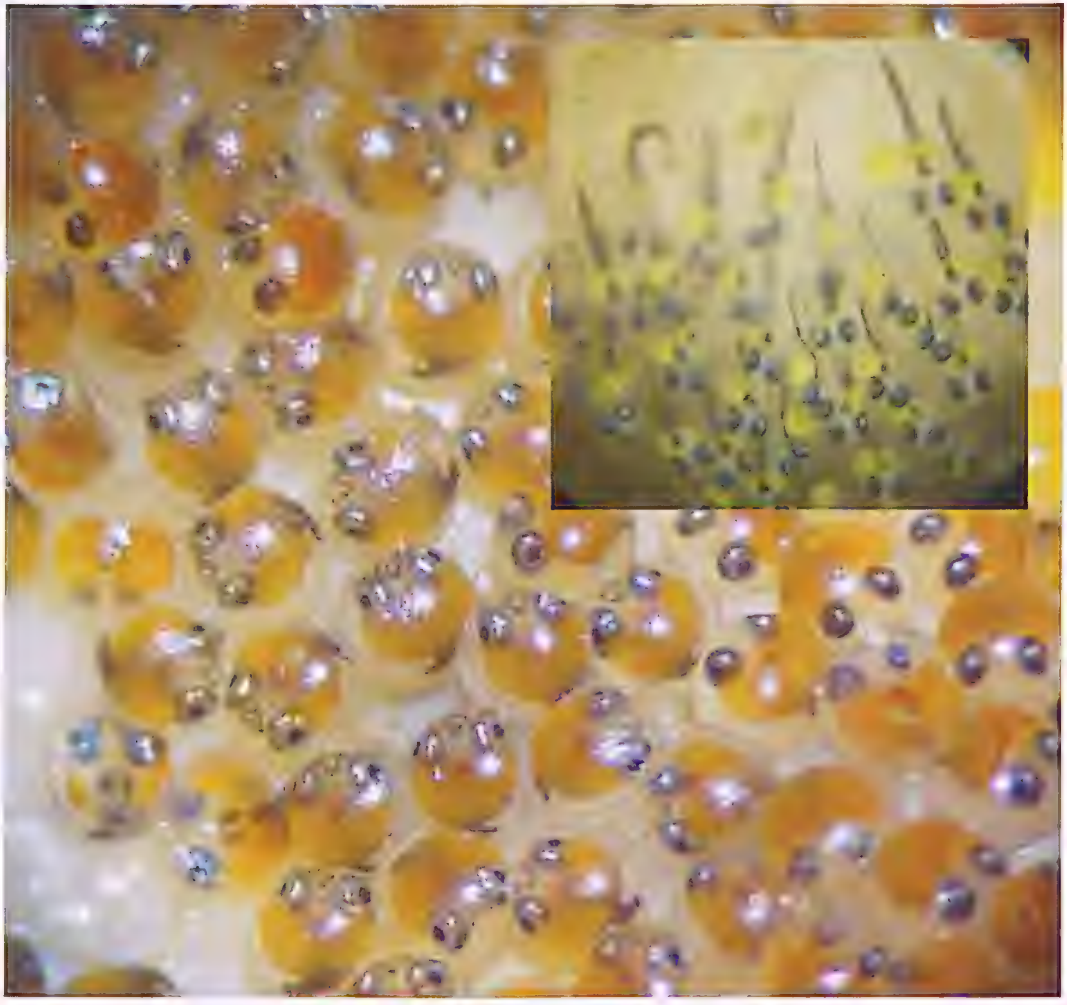


FIG. 6. Many thousands of adhesive eggs and yolk sac larvae (inset) of *Cryptocentroides gobioides* were found deposited on the inner surface of oyster shells deployed subtidally at both sites in October of both 2015 and 2016 (shell cultch treatment).

Table 4. Diversity of fish and invertebrate species observed to be associated with the natural shell cultch trays and three dimensional concrete spat collection units in Pumicestone Passage. Many species of coralline and encrusting algae, and colonial tunicates (*Symplegma* sp., *Botrylloides* sp.) were also evident (see Supplement Figure 5).

Common Name	Scientific Name	Months observed
Fishes		
Crested oyster goby	*Cryptocentroides gobioides*	Jan-Dec, Spawning in Oct
Estuarine stonefish	*Synanceia horrida*	Feb
Bengal sergeant	*Abudefduf bengalensis*	Jan-Dec
Fan bellied leatherjacket	*Monacanthus chinensis*	Aug
Highfin moray eel	*Gymnothorax pseudothyrsoideus*	Apr
Moses perch	*Lutjanus russelli*	Jan-Dec
False scorpionfish	*Centrogenys vaigiensis*	Nov
Silver biddy	*Gerres subfasciatus*	Jan-Dec
Striped cardinalfish	*Ostorhinchus fasciatus*	Apr
Bluebarred parrotfish	*Scarus ghobban*	Feb-Jun
Surgeonfish	*Acanthurus* sp.	Jan-Feb
Snapper	*Pagrus auratus*	May
Tarwhine	*Rhabdosargus sarba*	Jan-Dec
Yellowfin bream	*Acanthopagrus australis*	Jan-Dec
Crustacea		
Mud crab	*Scylla serrata*	Jan-Dec
Mangrove swimming crab	*Thalamita crenata*	Jan-Dec
Swimming crab	*Charybdis* sp.	Jan-Dec
Smooth handed crab	*Pilumnopeus serratifrons*	Dec-May
Porcellanid crab	F. Porcellanidae	Dec-Jun
Blue hermit crab	Clibanarius virescens	Jan-Dec
Xanthid crabs	F. Xanthidae	Jan-Dec
Greasyback prawn	*Metapenaeus bennettae*	Aug
Red handed shrimp	*Palaemon serenus*	Oct-May
Snapping shrimp	*Alpheus* sp.	Jun-Nov
Barnacles	*Balanus variegatus*	Jan-Dec
Unidentified amphipods	O. Amphipoda	Jun-Oct
Unidentified isopods	O. Isopoda	Apr-Dec
Molluscs		
Australian mud whelk	*Velacumantus australis*	Jan-Dec
Chiton	C. Polyplacophora	Jun
Dove snail	*Anachis* sp.	Jan-Dec
Moon snail	*Natica* sp.	Nov-Jan
Oyster borer	*Bedeva paivae*	Jan-Dec
Hairy mussel	*Trichomya hirsuta*	Spatfall Jan
Pale pearl oyster	*Pinctada albina*	Spatfall Mar-Jul
Pearl oyster	*Pinctada maculata*	Spatfall Mar-Jul
Pyramid periwinkle	*Nodilittorina pyramidalis*	Jul
Saddle shaped oyster	*Hyotissa imbricata*	Spatfall May-Sept
Sydney rock oyster	*Saccostrea glomerata*	Spatfall Oct-May
Sea hare	*Aplysia* spp.	Nov
Dendrodoris sp. ?	O. Nudibranchia	Aug-Oct

Ningi Creek in 1978/79 occurred between November and March, peaking in December. In the present study, recruitment was observed between October and May, peaking in January (Figures 3, 5), with the extended period possibly due to increased water temperatures around Ningi Creek in 2015/16 compared to 1978/79. When survival of settled spat was examined over several months n the monitor and clean treatments, it was evident that numbers of *S. glomerata* spat could build up over the summer months in both subtidal and intertidal areas, provided appropriate hard settlement substrates were provided (Figures 4, 5). Regular cleaning of settlement substrates appeared to improve spat settlement rates in intertidal areas, particularly in late summer (Figure 5), but lower survival of spat was observed in subtidal units given this treatment, particularly in February and March (Figure 5). A small number of spat (n = 12) were examined for infection by *Marteilia sydneyi* (causative agent of QX disease) in March 2016 but the parasite was not observed (B.K Diggles, unpublished data). Increased mortality rates of newly settled *S. glomerata* spat on subtidal collectors during February and March was therefore considered likely to be due to predation, as large numbers of fishes and crabs were observed to be closely associated with the subtidal units at that time of year. Reduced survival of newly recruited spat on subtidal units was observed only in the clean treatment (Figure 4, Supplement Figure 4), as a similar reduction in survival was not observed on subtidal units that were monitored only (Figure 4). This may suggest that the process of pressure cleaning the settlement units and removing films of silt and algae made newly settled spat more vulnerable to predation in subtidal areas, indicating that regular cleaning of settlement substrates is not necessary provided sufficient internal and inverted settlement areas are designed into spat settlement units to provide silt-free substrates for spat to attach.

Once recruitment ceased when water temperatures dropped below 24°C in May 2016, a steady rate of mortality continued throughout the autumn and winter months in all treatments, regardless of whether units were subtidal or intertidal (Figures 4, 5, Supplement Figures 3, 4). These mortalities of juvenile *S. glomerata* were apparently not due to infection by mudworm, but may have been due to QX disease, predation, or other causes including smothering due to blooms of cyanobacteria *Lyngbya* sp., brown algae *Ectocarpus fasciculatus* and/or jellyfish *Catostylus mosaicus*. Indeed, smothering by algae drifts (particularly *E. faciculatus*) may have contributed to mortality of juveniles during the cooler winter months when water clarity (and hence sun penetration) was highest, especially after water temperatures began to increase from their winter lows (Supplement Table 1, Supplement Figure 2). Historical studies of the population dynamics of oyster reefs in the United States found that natural mortality of oyster spat in the first year after settlement was around 50% (Winslow 1887). In the present study, survival of spat in the first year varied from a low of 16% for spat held subtidally on cleaned settlement units (Figure 4) to around 58% for spat held intertidally on uncleaned settlement units (Supplement Figure 3). In all treatments, the number of *S. glomerata* recruits began to increase again once water temperatures increased beyond 24°C in October 2016.

At no time during these experiments was there any evidence of infestation of any of the newly recruited *S. glomerata* by spionid mudworms. This provides further evidence to refute theories that introduction of "more virulent exotic species of mudworm" are responsible for loss of subtidal oysters in Australian estuaries (Ogburn et al. 2007). Observations from pre-eminent scientists at the time these losses began (Saville-Kent 1891), together with historical epidemiological evidence combined with modern scientific understanding of settlement cues and taxonomy of spionid polychaetes (Sebesvari et al. 2006; Read 2010; Walker 2011; Diggles 2013), all suggest that mudworm disease, (or, as Saville-Kent (1891) states "the mud disease") is not due to introduction of exotic species , but instead is due to "*the altered conditions of these rivers, brought about mainly through human agency*"(Saville-Kent 1891).

Regular (monthly) pressure cleaning of collectors to remove silt deposits and algal turfs increased *S. glomerata* spatfall on the vertical sides of collection units (particularly on intertidal units), as well as encouraged settlement of other bivalves including *Hyotissa imbricata*, *Pinctada albina*, and *Pinctada maculata*. These data suggest that an absence of clean settlement substrate significantly reduces mollusc biodiversity in Pumicestone Passage, which is consistent with knowledge that siltation and eutrophication result in greatly reduced species diversity in estuarine environments (Newell 2004; Kirby & Miller 2005; Grabowski & Peterson

2007; Beck et al. 2011; zu Ermgassen et al. 2016). Furthermore, these data suggest that loss of natural subtidal *S. glomerata* populations in Pumicestone Passage over the past 100 years is not due to a lack of available spat, but instead is probably due to multigenerational recruitment failure originating from a gradual reduction in availability of suitably clean spat settlement substrates (Diggles 2013).

Despite functional extinction of subtidal *S. glomerata* reef habitat in Pumicestone Passage (Diggles 2013), deployment of clean concrete blocks and shell cultch into subtidal areas resulted in successful recruitment of *S. glomerata* spat. Of these two settlement substrates, the natural shell cultch appeared far superior, attracting 10-90 times more *S. glomerata* spat and 28-135 times more invertebrates than concrete spat collection units on a unit weight basis (Tables 2, 3). When measured volumetrically, shell cultch remained superior to concrete spat collection units for attracting both *S. glomerata* spat (5–42 times more effective) and invertebrates (13–62 times more effective). The high attractiveness of natural shell cultch is likely to be due to its provision of chemical settlement cues (Tamburri et al. 2008, Vasquez et al. 2013), as well as its high surface area and high void volume (Kuykendall et al. 2015) with the shapes of the shells themselves providing a high percentage of nooks, crannies and rugosities including many inverted surfaces shielded from silt. Natural shell cultch is also advantageous for shellfish reef restoration due to its relatively light weight compared to concrete structures, making handling of raw materials easier, while the shells themselves become bound together into extensive reef systems by organic cement naturally secreted by recruited oysters (Burkett et al. 2010). Provided oyster shell cultch can be arranged into 3 dimensional high relief reefs (Schulte et al. 2009; Housego & Rosnam 2016) in hydrodynamically suitable arrangements (Colden et al. 2016), it would appear to be the best suited material for restoration of shellfish reefs in Pumicestone Passage either by itself (Burkett et al. 2010) or in conjunction with appropriate artificial base substrates that elevate and protect oyster shells from siltation (Sawusdee et al. 2015).

The now regular seasonal blooms of toxic and nuisance algae such as fireweed (*Lyngbya* sp.) and snotweed (*Ectocarpus fasciculatus*) together with high intensity of blooms of blue blubber jellyfish (*Catostylus mosaicus*) confirm that a significant reduction in environmental quality has occurred in Pumicestone Passage compared to historic baselines (Dennison and Abal 1999). Some authors have suggested that increased implementation of "no take" sanctuary zones will protect biodiversity and fisheries productivity in Pumicestone Passage and other areas of the Moreton Bay Marine Park (Pillans et al. 2007). However, when the mechanisms affecting this ecosystem are considered, it is clear that it will not spontaneously recover from its current degraded state if the remaining recreational fishing effort in Pumicestone Passage is removed (Diggles 2013). This is because "no take" sanctuary zones do not protect biodiversity whenever habitat and water quality are being degraded (Jones et al. 2004), highlighting an urgent need for active restoration (Creighton et al. 2015; Diggles 2015; Gilles et al. 2015a). The data collected here suggest that the processes driving changes to the Pumicestone Passage and wider Moreton Bay ecosystems appear primarily driven by declining water quality due to sedimentation, eutrophication and other anthropogenic changes derived from catchment development. Hindsight shows that these processes have been occurring for decades over many inshore ecosystems in Queensland (Roff et al. 2013), with the problem being no better articulated than by William Saville-Kent, who in his paper to the Queensland Parliament in 1891 observed:

"*Through the clearance of the land and the establishment of townships and settlements throughout the watersheds of these rivers, the rainfall which in former days fell upon and was more completely absorbed by the primeval forests is now carried quickly away, and emptied by drains and culverts into the watercourses communicating with the rivers. Simultaneously with this augmented discharge of water into the rivers a vastly larger quantity of sediment is brought down, accompanied by a considerable percentage of organic and chemical pollution that had no place in the composition of the water under those conditions in which the oysters originally grew and flourished. This greatly augmented accession of flood water, with its accompaniment of sediment and chemical pollution, cannot exert other than a very deleterious influence upon the riverine oyster fisheries.*" (Saville–Kent 1891)

Because this process of degradation has been occurring for several human generations, it is important to recognise that shifting baselines (Pauly 1995; Papworth et al. 2008) already pervade management actions in Moreton Bay. This is demonstrated by

review of historical management documents over time, which reveals that ecosystem health measurements1 currently being made available to the public are not directly comparable to those from previous years (Dennison and Abal 1999). It is therefore very important that management and restoration efforts in Pumicestone Passage and wider Moreton Bay refocus on re-establishing baselines, and developing targets for restoration of water quality (e.g. nutrient and sedimentation reduction), habitat (e.g. regeneration of wetlands, seagrasses and shellfish reefs) and fisheries.

The results presented here confirm that *S. glomerata* spat can successfully recruit to hard subtidal substrates in Pumicestone Passage in the form of either shell cultch (with its high surface area and high attractiveness for conspecific spat and invertebrates) or artificial substrates which appear suitable provided they are designed with sufficient internal and inverted surface area to provide settlement substrates free of siltation. Observations of commercially important fish and invertebrates species associating with the experimental modules in the present study hint at a high likelihood of improved biodiversity and fisheries productivity if these reefs can be restored (Peterson et al. 2003; zu Ermgassen et al. 2016). However, more detailed study is required to properly quantify these biodiversity and fisheries productivity metrics. Nevertheless, these results suggest that restoration of subtidal shellfish reefs in Pumicestone Passage using natural recruitment processes remains feasible, with success most likely if appropriately designed clean settlement substrates (preferably natural shell cultch) are placed into the ecosystem during natural recruitment periods in late spring and throughout the summer months.

ACKNOWLEDGEMENTS

The author thanks Carlo Sain, Fred Palin and Ian McLeod for providing support during fieldwork, Jeff Johnson for help with identification of fishes, Nicholas Paul for help identifying algae, and Jeff Ahchay and Rob King from Sunfish for supplying oyster reef balls and key references. The Moreton Bay Regional Council and Unity Water provided partial funding to support fieldwork and purchase of reef balls. This research was conducted under Marine Parks permit # QS2016/MAN343.

1 http://healthywaterways.org/reportcard#overview/2016/condition

LITERATURE CITED

ALLEWAY HK, Connell SD 2015. Loss of an ecological baseline through the eradication of oyster reefs from coastal ecosystems and human memory. Conservation Biology 29: 795-804.

BECK MW, BRUMBAUGH RD, AIROLDI L, CARRANZA A, COEN LD, CRAWFORD C, DEFEO O, EDGAR GJ, HANCOCK B, KAY M, LENIHAN H, LUCKENBACH MW, TOROPOVA CL, ZHANG C, GUO X 2011. Oyster reefs at risk and recommendations for conservation, restoration and management. Bioscience 61: 107-116.

BURKETT JR, HIGHT LM, KENNY P, WILKER JJ (2010). Oysters produce an organic-inorganic adhesive for intertidal reef construction. Journal of the American Chemical Society 132: 12531-12533.

COLDEN AM, FALL KA, CARTWRIGHT GM, FRIEDRICHS CT 2016. Sediment suspension and deposition across restored oyster reefs of varying orientation to flow: Implications for restoration. Estuaries and Coasts 39: 1435–1448.

CREIGHTON C, BOON PI, BROOKES JD, SHEAVES M 2015. Repairing Australia's estuaries for improved fisheries production – what benefits, at what cost ? Marine and Freshwater Research 66: 493-507.

DENNISON WC, ABAL EG 1999. Moreton Bay Study. A scientific basis for the Healthy Waterways Campaign. South East Queensland Regional Water Quality Management Strategy, Brisbane 246 pgs.

DIGGLES BK 2013. Historical epidemiology indicates water quality decline drives loss of oyster (*Saccostrea glomerata*) reefs in Moreton Bay, Australia. New Zealand Journal of Marine and Freshwater Research 47: 561-581.

Diggles BK 2015. Protection and repair of Australia's shellfish reefs – Southern Queensland Report. DigsFish Services Client Report DF15-01. September 2015. 27 pgs. http://restorepumicestonepassage.org/wp-content/uploads/2014/04/NESP-Project-Southern-Queensland-Report-DigsFish.pdf

GILLES CL and 22 other co-authors 2015a. Scaling up marine restoration efforts in Australia. Ecological Management and Restoration 16: 84-85.

GILLES C, CREIGHTON C, MCLEOD I (eds). 2015b. Shellfish reef habitats: a synopsis to underpin the repair and conservation of Australia's

environmental, social and economically important bays and estuaries. A report for the national Environmental Science Programme: Marine Biodiversity Hub, Tropwater report No. 15/60. https://research.jcu.edu.au/tropwater/research-programs/coastal-estuarine-ecology/shellfish-reef-protection-and-repair/ShellfishreefhabitatsFinalVersion.pdf

GRABOWSKI JH, PETERSON CH 2007. Restoring oyster reefs to recover ecosystem services. Pp. 281-298 in Cuddington, K., J. Byers, W. Wilson, and A. Hastings (editors). Ecosystem engineers: Plants to Protists. Academic Press, Boston.

HOUSEGO RM, ROSMAN JH 2016. A model for understanding the effects of sediment dynamics on oyster reef development. Estuaries and Coasts 39: 495–509.

JONES GP, MCCORMICK MI, SRINIVASAN M, EAGLE JV 2004. Coral decline threatens fish biodiversity in marine reserves. Proceedings of the National Academy of Sciences of the United States of America. National Academy of Sciences 101: 8251-8253.

KIRBY MX, MILLER HM 2005. Response of a benthic suspension feeder (*Crassostrea virginica* Gmelin) to three centuries of anthropogenic eutrophication in Chesapeake Bay. Estuarine Coastal and Shelf Science 62: 679-689.

KUYKENDALL KM, MORENO P, POWELL EN, SONIAT TM, COLLEY S, MANN R, MUNROE DM (2015). The exposed surface area to volume ratio: is shell more efficient than limestone in promoting oyster recruitment ? Journal of Shellfish Research 34: 217–225.

MCEWAN J, GABRIC AJ, BELL PRF 1998. Water quality and phytoplankton dynamics in Moreton Bay, south-eastern Queensland. I. Field survey and satellite data. Marine and Freshwater Research 49: 215-225.

MORELLI G, GASPARON M, FIERRO D, HU W, ZAWADZKI A 2012. Historical trends in trace metal and sediment accumulation in intertidal sediments of Moreton Bay, southeast Queensland, Australia. Chemical Geology 300-301: 152–164.

NEWELL RIE 2004. Ecosystem influences of natural and cultivated populations of suspension feeding bivalve molluscs: a review. Journal of Shellfish Research 23: 51-61.

OGBURN DM, WHITE I, MCPHEE DM 2007. The disappearance of oyster reefs from eastern Australian estuaries – Impact of colonial settlement or mudworm invasion? Coastal Management 35: 271-287.

PAPWORTH SK, RIST J, COAD L, MILNER-GULLAND EJ 2008. Evidence for shifting baseline syndrome in conservation. Conservation Letters 2: 93-100.

PAULY D 1995. Anecdotes and the shifting baseline syndrome of fisheries. Trends in Ecology and Evolution 10: 430.

PETERSON CH, GRABOWSKI JH, POWERS SP 2003. Estimated enhancement of fish production resulting from restoring oyster reef habitat: quantitative valuation. Marine Ecology Progress Series 264: 249-264.

PILLANS S, ORTIZ JC, PILLANS RD, POSSINGHAM HP 2007. Impact of marine reserves on nekton diversity and community composition in subtropical eastern Australia. Biological Conservation 136: 455-469.

POTTER MA (1984). Selection of areas for the commercial collection of spat of the Sydney rock oyster , *Saccostrea commercialis*, in subtropical Moreton Bay, Australia. Queensland Journal of Agricultural and Animal Sciences 41: 125-134.

READ GB 2010. Comparison and history of *Polydora websteri* and *P. haswelli* (Polychaeta: Spionidae) as mud-blister worms in New Zealand shellfish. New Zealand Journal of Marine and Freshwater Research 44: 83-100.

ROFF G, CLARK TR, REYMOND CE, ZHAO J, FENG Y, MCCOOK LJ, DONE TJ, PANDOLFI JM 2013. Palaeoecological evidence of a historical collapse of corals at Pelorus Island, inshore Great Barrier Reef, following European settlement. Proceedings of the Royal Society B. doi: 10.1098/rspb.2012.2100.

SAVILLE-KENT W 1891. Oysters and oyster fisheries of Queensland. Presented to both Houses of Parliament by Command. Department of Fisheries, Brisbane, 30th June, 1891.

SAWUSDEE A, JENSEN AC, COLLINS KJ, HAUTON C 2015. Improvements in the physiological performance of European flat oysters *Ostrea edulis* (Linnaeus, 1758) cultured on elevated reef structures: Implications for oyster restoration. Aquaculture 444: 41–48.

SCHULTE DM, BURKE RP, LIPCIUS RN 2009. Unprecedented restoration of a native oyster metapopulation. Science 325: 1124–1128.

SEBESVARI Z, ESSER F, HARDER T 2006. Sediment–associated cues for larval settlement of the infaunal spionid polychaetes *Polydora cornuta* and *Streblospio benedicti*. Journal of Experimental

Marine Biology and Ecology 337: 109-120.

SMITH G 1981. Southern Queensland's oyster industry. Journal of the Royal Historical Society of Queensland 11: 45-58.

SMITH G 1985. The Queensland oyster fishery: An illustrated history: Queensland Department of Primary Industries. 111 pgs.

TAMBURRI MN, LUCKENBACH MW, BREITBURG DL, BONNIWELL SM 2008. Settlement of *Crassostrea ariakensis* larvae: effects of substrate, biofilms, sediment and adult chemical cues. Journal of Shellfish Research 27: 601-608.

VASQUEZ HE, HASHIMOTO K, YOSHIDA A, HARA K, IMAI CC, KITAMURA H, SATUITO CG (2013). A glycoprotein in shells of conspecifics induces larval settlement of the Pacific oyster *Crassostrea gigas*. PloS One 8: e82358.

WALKER LM 2011. A review of the current status of the *Polydora*-complex in Australia and a checklist of recorded species. Zootaxa 2751: 40-62.

WINSLOW F 1887. Deterioration of American oyster beds. The Popular Science Monthly 20: 29-43.

ZU ERMGASSEN PS, SPALDING MD, GRIZZLE RE, BRUMBAUGH RD 2012. Quantifying the loss of a marine ecosystem service: filtration by the eastern oyster in US estuaries. Estuaries and Coasts 36: 36-43.

ZU ERMGASSEN PS, GRABOWSKI JH, GAIR JR, POWERS SP 2016. Quantifying fish and mobile invertebrate production from a threatened nursery habitat. Journal of Applied Ecology 53: 596–606. Author Profile

Editor note. Supplementary material to this paper may be obtained at www.digsfish.com/roysocsupplementary.pdf

AUTHOR PROFILE

Dr Ben Diggles is a marine biologist (University of Queensland) with over 25 years specialist experience in study of the health of aquatic animals and their environment. In his spare time, Dr Diggles studies the effects of declining water quality on our estuaries, and is active in his local community developing solutions to these problems, like shellfish reef restoration. Ben is also the great, great grandson of Silvester Diggles, who was a founder of the Queensland Philosophical Society (predecessor of the Royal Society of Queensland), and helped establish the Queensland Museum.

THE DECLINE OF MELLIFEROUS NATIVE FLORA FOR EUROPEAN HONEY BEES IN QUEENSLAND - SOME REFLECTIONS

KEITH, D.

INTRODUCTION

After World War II, from 1946, the apiculture industry in Queensland grew substantially over a period of 50 years. Production of apiary products, always subject to seasonal variations, peaked about 1996. The industry in Queensland has declined over the past twenty years largely due to loss of native floral resources and will continue to decline under current state government policy settings. Conservationists and apiarists have largely the same interests, and science is their witness.

This paper discusses the loss of native floral resources over the past 70 years, reflecting the need for a change of government attitude to some land management policies if current levels of production and the pollination needs of more intensive agriculture are to be met in Queensland. The narrative is a story of incremental and widespread decline of an industry vital to the public benefit, largely unmarked in the media.

THE INDUSTRY IN QUEENSLAND

European honey bees, *Apis mellifera*, were successfully imported into Australia in 1822 and were no doubt taken to all the new settlements. However, honey bees increase the number of colonies by swarming – that is some of the bees leave the mother colony to establish a new colony or colonies. Professional apiarists employ swarm control management techniques to ensure strong colonies and maximise hive production.

The early arrivals came to a "honey bee el-dorado" and naturalised very quickly because by the time of closer settlement honey bees were ubiquitous in the environment wherever there was permanent water. Most early apiarists, including my forebears, obtained their original colonies from hollow trees containing honey bee colonies during timber felling.

Ninety percent of Queensland's melliferous (nectar and pollen producing) resources are native plants with eucalypt species being by far the most important. Our native eucalypt flora buds and flowers in response to rainfall events, and for each species a good general flowering almost never occurs annually. Each species may not flower until years later depending on rainfall events. As a result, the industry in Queensland is highly migratory with apiaries being moved approximately six times annually to access various resources. A Queensland apiarist may need to have access rights for up to 20 apiary sites per individual apiary.

Because of climate suitability most apiculture in Queensland occurs within 300 kms of the southern border with New South Wales, with much lower levels of activity in the near coastal region north to Cooktown and on the Atherton Tableland.

A PERSONAL JOURNEY – IN TIME AND SPACE

I grew up at Richlands, a small crop and poultry farming district south west of the Brisbane CBD which during my childhood was surrounded by forests. In 1946, my father migrated many of his hives to the Rocky Creek district, south of Millmerran on the Darling Downs, to access the flowering of western tea-tree *(Melaleuca lanceolata).* He had a Dodge car converted to a utility by removing the rear seat and replacing it with a tray back. (This process was common and preceded manufactured utilities). He also had a trailer and moved about 20 hives at a time. Our family of six moved into a cottage on a dairy farm and I attended Rocky Creek School for about three months. Rocky Creek had a cheese factory and there was a butter factory in Millmerran. Most farms in the district were mixed grain and dairy with residual patches of native flora left as shelter belts. Features of the district are the long extinct volcanoes Mt. Emlyn, Mt. Basalt and Mt. Domville.

Migratory beekeeping was in its infancy in 1946 and was assisted by improvements to vehicles during the war. Apiaries were relatively small as all apiary functions were manual – for example an apiary of 600 hives now operated by one person would at that time have required four people. While my father's transport was small, most apiarists had second-hand trucks. It was a matter of great wonder when some

years later he purchased a new truck. Choice honey returned the producer 7½ pence per lb. The wholesale price of choice honey had risen to 9½ pence per lb. when I joined the industry in 1954 and was still subject to wartime price control in Queensland.

The ongoing loss of native forest resources on the coastal plains of south-east Queensland caused the writer to move headquarters to the southern Darling Downs in 1969. We produced our last significant honey crop from the coastal lowland in 1967 and the Darling Downs was part of our normal seasonal migrations depending on seasonal flowering prospects. With only one exception, we then carried on a successful business limiting our migrations to 500km from our headquarters near Inglewood; however, many apiarists migrated much larger distances as vegetation resources declined.

BEEKEEPING IN SELECTED REGIONS

THE FORESTS AND WOODLANDS OF THE VOLCANIC AND DEEP BLACK SOILS OF THE DARLING DOWNS

The original vegetation in the Rocky Creek District was brigalow *(Acacia harpophylla),* belah *(Casuarina cristata),* with *Melaleuca lanceolata,* a mid-storey plant, occurring with brigalow or belah or as pure stands sometimes in association with narrow leaf box *(Eucalyptus pilligensis).* This resource was limited but significant in that it attracted apiarists from Warwick, Tenterfield and Brisbane. At that time there was demand for food for Britain following the war and dairy farming was a major industry on the Darling Downs.

By 1960 virtually the whole district had stopped dairying and converted to grain growing and many of the modest sized holdings were amalgamated. The properties were cleared from fence to fence and today few melaleucas remain, mainly on road verges. Anyone visiting the district after 1960 would find it hard to believe *Melaleuca lanceolata* produced commercial honey crops there.

While this resource was small, there were significant apiculture resources in the far larger Condamine River catchment area. In 1946 much of the Darling Downs was still grazing land on native pastures, as well as dairying, and there were significant areas of River Red Gum *(Eucalyptus camaldulensis)* which provided apiarists with a major honey flow seasonally. More intensive cropping came to the Downs with irrigation in the 1960s and the rich deep soils were cleared to the river bank. As well, major flooding in 1956 and 1976 saw the formation of a Trust to remove vegetation in the water course. The ribbons of the few remaining trees were exposed to degradation by flocks of cockatoos, possums and insects, and now are usually too degraded to flower successfully. The relatively small western tea-tree resource was important as it was not only a short migration from the river gum but it commenced flowering as the river gum honey flow ended.

The almost total destruction of western tea-tree left me with a feeling of loss. When we built our home and headquarters at Coolmunda Dam in 1972, I obtained seeds from roadside trees and had them germinated at nurseries, planting a couple of groves on our small property which we named "Lanceolata".

THE FORESTS OF THE COASTAL PLAINS

In the 1950s large areas of forest remained on the coastal plains where soils or topography were unsuitable for the agricultural practices of that time. The forests were periodically logged as a timber resource. These forests sustained many early beekeepers and the wide variety of flora allowed many apiaries to be non-migratory. Most of the species growing in these forests were of value to the apiculture industry from time to time. The most valued species was grey ironbark (Eucalyptus drepanophylla). Vast areas of these forests have since been cleared for urbanisation and acreage developments. Few remain except in state reserves of various denominations. Today there are few apiarists able to utilise the remnants of these forests, where once there were many, and production is minimal.

THE TEA-TREE (MELALEUCA QUINQUENERVIA) FORESTS

While tea-tree was one of the multitude of species in coastal lowland forests, the major areas were in extensive swampy areas between the Queensland - New South Wales' border and Maryborough. In the 1950s this resource was utilised by most Queensland commercial apiarists, even those based on the Darling Downs. Tea-tree is unusual in that the same trees flower a number of times each season with the main flowerings in April, May and June. Tea-tree is a major source of both pollen and nectar. The pollen, being the source of protein for the bees, allows the hives to breed young bees going

into winter, ensuring hives were well populated for winter and spring-flowering flora.

Most of these lands were found to be suitable for growing exotic soft woods which have no apicultural value or were cleared for establishing 'improved' pasture species for cattle. The remnant swamps are still utilised mainly by smaller-scale beekeepers as there are few areas able to sustain commercial apiaries.

FORESTS OF THE COASTAL RANGES

These ranges include the Border Ranges, the Conondale – Jimna – Manumba Ranges, the Great Dividing Range south of Crows Nest and the D'Aguilar Range. While the tea-tree swamps and the coastal plains provided the main autumn/winter/spring resources for south-east Queensland apiarists, most honey is produced in summer. In the case of south-east Queensland flora, flowerings move from near the coast to the higher altitudes as the season progresses. As a result, the coastal ranges provide the largest honey crops for south-east Queensland apiarists. Grey ironbark *(Eucalyptus drepanophylla)* and brush box *(Lophostemon conferta)* are the two most important species, both producing copious quantities of choice honey.

FORESTS AND WOODLANDS OF THE SOUTHERN DARLING DOWNS

In 1969, the Warwick district was the major centre of apiary production in Queensland, where about 20 commercial apiarists had their headquarters. Also Stanthorpe, Texas, Inglewood, Millmerran, Allora, Oakey, Clifton, Dalby and Toowoomba all had resident apiarists with significant commercial enterprises. State forests were, and still are, a very valuable resource for apiarists on the Darling Downs, but even here there are plans to create national parks, with possible adverse consequences for the apiculture industry in terms of access. Unfortunately in the 40 years we were beekeeping on the southern Downs, we witnessed enormous loss of woodland resources.

In Queensland the most valued eucalypt for apiculture is yellow box *(Eucalyptus melliodora)*. The yellow box resource is limited in extent to the Traprock and granite lands of the southern Darling Downs. As well as yellow box, the Traprock lands contained a multitude of other nectar producing eucalypts and were a major production area for many Queensland apiarists.

Much of the development of the Traprock region was for wool production but this industry has also suffered an enormous decline and both industries are significantly reduced in the district. The Warwick district, Toowoomba and smaller towns on the Darling Downs are now home to very few commercial beekeepers.

WOODLANDS OF THE WESTERN WARREGO AND CHANNEL COUNTRY

A major new resource became accessible to Queensland apiarists in the 1970s and has, to some extent, provided a replacement resource for apiarists capable of very long migrations of hives. Yapunyah *(Eucalyptus ochrophloia)* grows in low lying alluvial lands adjacent to water courses in a number of river catchments west of Charleville and Cunnamulla, including the Paroo and Bulloo catchments and others. As well as the highly productive yapunyah on flooded lands, adjoining lands have a multitude of native shrubs and wildflowers in their season, as well as bimbil box *(Eucalyptus populnea)*. Improvements to both roads and vehicles allowed this resource to be viably accessed by Queensland beekeepers in the 1970s. For our business, migrations away from the southern Downs increased in the 1980s.

PARTICULAR SPECIES

THE LEPTOSPERMUM (MANUKA) RESOURCE

Australia has more than eighty species of Leptospermum, and prior to the 1990s these plants were avoided if possible by apiarists. It was commonly called "jelly bush" because the honey produced from some species sets like jelly in the honey combs, making it impossible to remove in standard honey extractors. The honey has a strong flavour and had no commercial value. New Zealand has few species but relatively large areas of *Leptospermum scoparium* with the common name "Manuka".

In the 1990s Dr Peter Molan, a New Zealand researcher, discovered a special anti-bacterial property in Manuka honey. In the twenty years since, the discovery has gone through exhaustive trials and the efficacy of the honey in combatting harmful and antibiotic resistant bacteria has been established.

Leptospermum (manuka) honey is in worldwide demand, well beyond current production. The level of antibacterial activity is now scientifically measured and the honey is priced according to the level of activity. Research is continuing into the antimicrobial

properties of the many Australian leptospermums, and suitable leptospermums species are now being planted in some areas to increase resources.

The very high value of Manuka honey has caused a revolution within the New Zealand apiary industry with extreme increased pressure for access to this resource. Similar pressures are developing in Australia. Production of leptospermum honey is challenging because the plant provides little pollen, but the high prices paid will see supplementary feeding with pollen substitutes becoming viable. Leptospermum production could become a major industry segment, but is another segment that requires continued availability to native forest resources in order to maintain colony strength.

MACADAMIA, CLOVER AND CANOLA

Whilst bees are essential to maximise fertilisation of many crops, macadamias and canola are currently the only crops widely sought by apiarists for their floral resources. Both these plants benefit from honey bee pollination and produce pollen and nectar in sufficient quantities to provide good bee breeding conditions as well as a honey flow. Unfortunately since the advent of neonicotinoid insecticide dressing of canola seed, results for apiarists from this source have declined. The use of this insecticide application is under a temporary ban in Europe and its toxicity on insect pollinators is subject to research.

White clover was once an important plant for apiculture, particularly in the Mary River valley in Queensland and in the New England Tableland district in New South Wales. The decline in the dairy industry and replacement of clover with rye grass has seen the importance of white clover decline quite significantly for the industry and it is now of low value.

While many crops could be valuable to apiculture, pesticide applications render most to be of high risk and are avoided. The expansion of cotton growing resulted in large areas of woodland being cleared and the remaining useful areas "out of bounds" for apiarists due to pesticide use.

FACTORS THAT ASSISTED INDUSTRY GROWTH PRIOR TO THE MID 1990S

EXTENSION AND RESEARCH BY THE DEPARTMENT OF PRIMARY INDUSTRY

After war service Charles (Charlie) Roff joined the Department as an apiary inspector. Charlie kept abreast of industry innovations and provided a large volume of extension information through *DPI Notes*, the *Queensland Agricultural Journal* and field days. He visited many parts of Queensland and provided a greatly increased knowledge of flora in various districts. Charles Roff and S.T. Blake published a series of articles in the Queensland Agricultural Journal 1953-56 that were compiled into a book entitled "The Honey Flora of South-East Queensland" in 1958. Following surveys of other areas, further articles were combined with the original book to produce "The Honey Flora of Queensland" (1972). Charles Roff was joined in the 1960s by John Rhodes, and later by Roger Goebel, providing human resources to undertake research projects.

EDUCATION AND RESEARCH AT QUEENSLAND AGRICULTURAL COLLEGE, GATTON

After completing a Diploma Course at Queensland Agricultural College, Lawes (Gatton College), Graham Kleinschmidt joined the College staff as a Junior Assistant in the Apiary Section in December, 1951. Graham became the senior apiculturist at a young age in 1955 and gained a wealth of practical experience in a close association with Charles Roff, and by working with successful apiarists at that time.

Prior to 1967 there was little apiculture research in Queensland. Over a 20 year period with some funds from the Australian Honey Board, and later from the Honey Research Council, Graham led a tiny research team that conducted over 34 research projects. All of these projects utilised commercial numbers of beehives in the College's own commercial sized apiary. Armed with these research results many mysteries and myths of beekeeping in Queensland were replaced by facts that led to decisions resulting in increased productivity of beehives.

In 1986 in recognition of the value to the industry of the research by Graham Kleinschmidt et al, the Queensland Beekeepers' Association combined with the Queensland Agricultural College to publish 34 research papers in a single volume ("Graham J. Kleinschmidt Research Papers") for sale to apiarists to ensure ready availability of this invaluable knowledge to the industry.

IMPROVED TRANSPORT AND ROADS

In 1946 trucks were relatively small and most roads were gravel or dirt, and a migration of 300km was

extreme. Over time both trucks and roads improved, so as resources became scarce or depleted, apiarists became able to carry larger apiaries over longer distances, with apiaries of 200 colonies transported over distances of 1000km now often occurring.

TECHNICAL ADVANCES

In the 1940s most apiarists had a mobile honey extracting plant and camped out while harvesting honey which was packed into 60 lb tins. All operations were manual. The 1960s and 1970s saw remarkable technical advances – better and larger trucks, bee hive loaders, and automatic stainless steel extracting machinery established in central extracting premises. Today most honey is transported in 1000 litre containers and manual work in minimised.

In the 1980s honey bee genetic improvement programs aided productivity in the beekeeping industry.

Whilst these advances have helped apiarists cope with the loss of resources in the short term, the industry is clearly in decline. The loss of natural vegetation resources, and the further potential loss of access to major resources, means that investment in the industry is limited and this in turn is accelerating decline.

POLICIES WORKING AGAINST THE INDUSTRY

THE REGIONAL FOREST AGREEMENT

The South East Queensland Forest Agreement of 2004 saw the inclusion in the national park estate of the state forests of the coastal ranges in south-east Queensland which were most productive for apiculture. As the industry was not considered appropriate in national parks in Queensland, it was given until 2024 to find alternative resources, of which there are none or at least very few.

Although there was a precursor Comprehensive Regional Assessment of the South East Queensland Forests costing many millions of dollars and in which the Queensland Beekeepers' Association participated to the utmost extent, this knowledge appears to have been of little influence in finalising the SEQ Forest Agreement. The government of the day allowed the President of the Australian Rainforest Conservation Society and the Chairman of the Timber Board to decide the outcomes of this assessment, and the Agreement was very detrimental to the apiary industry.

Two representatives of the Queensland Beekeepers' Association met with two representatives of the Department of Environment and Heritage in Toowoomba on 14th October, 1994 in an endeavour to reach an agreement that would ensure continued beekeeping in resources traditionally used by the apiary industry being converted to national park. The major points of agreement were summarised in a subsequent letter from the Minister (Robson 1994) :

- Discussion with relevant officers to ensure appropriate sites are accommodated in the Conondale Range as conservation park (or resource reserve), instead of national park. (Beekeeping can be permitted in conservation parks and resource reserves.)
- DEH and QBA to do their utmost to negotiate access for beekeepers to the other five beekeeping areas in national parks currently due to expire on 25th May, 1996.
- The negotiation of access / resource security to proposed national parks including extensions to Bunya Mountains National Park and the transfer of state forests to national parks tenure in the Wet Tropics and the Scenic Rim.

The negotiations in Toowoomba provided a satisfactory outcome for the industry and continuing access to these valuable resources.

The agreement achieved in October 1994 was reflected in the Protected Area Policy Manual General Operations Policy No. 1.10.8 - Beekeeping in Protected Areas - approved 22nd April, 1997. In spite of this hard-won agreement to provide access to traditional apicultural resources in future national park acquisitions, it was ignored in the SEQ Regional Forest Agreement, as was the knowledge generated in the SEQ Comprehensive Regional Assessment.

If the current decision is adhered to, that is, loss of access to the most productive forests in 2024, the apiary industry in Queensland will be seriously debilitated and many remaining apiary businesses will become unviable. Pollination of many crops depends on the availability of honey bees and that will no longer be able to be maintained without ongoing seasonal migratory access to these valuable forests.

CONVERSION OF LEASEHOLD LANDS TO FREEHOLD

Prior to the introduction of broad-based controls of tree clearing on all tenures in the late 1990s, clearing native vegetation on leasehold land was controlled through conditions of leasehold tenure, but was

largely unregulated on freehold tenure.

In the 1950s the Queensland Beekeepers' Association sought and obtained a level of protection for a small number of yellow box trees per acre of Crown Land. At the time this provided adequate protection of this resource as almost all grazing properties in the Traprock district (the major area in southern Queensland for yellow box) were leasehold. A government decision, subsequent to 1957, provided for the freeholding of large areas of leasehold land in Queensland, and this included virtually all the yellow box lands. When leasehold is converted to freehold, ownership of the trees passes from the state to the purchaser.

In the early 1970s Tordon tree poison came on the market followed soon by Velpar. At the same time a period of prosperity occurred for the grazing industry and very large bulldozers became available. Land clearing and tree destruction on the Traprock lands, now freehold, was massive, particularly on the areas where yellow box flourished. My estimation is that 90% of the yellow box that was growing in 1969 has now been cleared.

CONVERSION OF RESERVES TO FREEHOLD

As well as the freeholding of grazing leases , the government of the day closed many camping and water reserves no longer needed for droving of stock, with a consequent loss of amenity for the public for camping and fishing, as well as destruction of vegetation resources for wild life as well as the beekeeping industry.

In 1989, the Queensland Beekeepers' Association learned of a proposal to freehold a remaining camping and water reserve in the Traprock area. This reserve contained representative areas of most of the species found in the Traprock lands and had significant conservation and apicultural value. Representations were made to government by the Association and another interested party. While the change in tenure had received government approval, the full processes of transfer had not been completed prior to the 1989 election. After the change of government, the transfer was never completed and the area remains a valuable state reserve.

Protection of reserves of this kind should not depend upon lobbying by non-government organisations. The apiary industry lacks confidence that these scattered reserves and stock routes are sufficiently secure against alienation, clearing and over grazing.

THE APIARY INDUSTRY AND CONSERVATION

The Queensland Beekeepers' Association (QBA) was inaugurated in 1886 and has consistently sought the retention of native flora and has a legitimate argument in saying "beekeepers are the original conservationists". Apiarists work close to nature and need to have a sound knowledge of flora, and most have a significant interest in the natural environment.

In the 1970s and 1980s, some hypotheses were raised by conservationists that honey bees could be causing competition and alteration to native biota. Subsequent research by D. Paton, University of Adelaide 1990-91; M.Schwarz *et al.*, Latrobe University 1991-92; and B. Oldroyd *et al.*, Latrobe University 1994 took account of the practice of the managed honey bee industry of migrating apiaries to areas of floral abundance, and therefore resource abundance, and found there was no long term adverse effect on the reproductive success of native fauna and flora.

The national peak industry body until 1997 (the Federal Council of Australian Apiarists' Associations / FCAAA) adopted the policy document "Honey Bees in Australian Conserved Forests 1987". This document was revised in 1996, and revised again in 2005 by the current peak industry body (the Australian Honey Bee Industry Council / AHBIC). The document acknowledged the concerns of all hypotheses raised and provided advice on research projects that investigated these issues. In short, for the purposes of this paper, the research to date, provided it recognised that managed honey bees are temporarily in the environment during periods of plenty, found there were ample resources and no adverse effect on native biota.

There is a divergence within national parks administration in the various states of the practical application of national park principles. Some states, recognising the resource needs of the apiary industry, the value of apiculture to the public benefit in agriculture, and the lack of discernible damage to biota by the managed migratory honey bee industry, provide sites for managed bees. Provision was made for continued access for the industry to national parks in Queensland in the 1980s, and the then Director

of the Environment Department, Graham Saunders, outlined this position in a Charles Roff Memorial Address to a QBA Conference. Des Boyland, Director of the Conservation Branch of the Department of Environment and Heritage, stated in an address to the QBA in 1995 that Queensland had taken a firmer stance against beekeeping than other states.

Crown Law advised the government that because of the inclusion of the "Cardinal Principle" and the "Precautionary Principle" in the *Nature Conservation Act 1992*, allowing beekeeping in national parks would be illegal.

The Queensland Beekeeping Industry Consultative Committee (BICC) was established in 1990 after a request to the previous government in 1989 was shelved pending an election. The BICC provides a forum by which the beekeeping industry can raise and discuss issues that have an effect on the industry with representatives of relevant government departments. As the threat of loss of access to new national parks to be created following the 1989 Queensland election became real, the BICC was requested to undertake further research into the effect of managed bees in the conserved environment. With limited resources and a reasonably large body of research into issues of concern to conservation, BICC Chairman John Walthall commissioned a review of research already conducted. This review was undertaken by Owen Seeman under the leadership of Professor Gordon Gordh, Department of Entomology, University of Queensland and findings were presented in 1994.

The final paragraph of "The Impact of Managed Honey Bees on Native Australian Animals and Plants" (Seeman 1994) stated: "In conclusion, not enough evidence exists to reject the null hypothesis that 'managed honey bees have little or no long term impact on the environment'. On the contrary, most of the available data suggests that any possible effects a migratory, commercial apiary may have would be temporary."

NOT JUST HONEY PRODUCTION

For most of European farming history in Queensland, feral honey bees provided some of the pollination for crops. This happened largely unnoticed. With changes to more intensive cropping and larger areas of crops and a massive decline in the feral honey bee population due to land clearing and crop pesticide management, as well as a debilitating influx of bee hive diseases since 1980, requirements for pollination by managed bees are rapidly increasing.

This increase in demand for bees for pollination is occurring at a time when the industry is in decline largely due to loss of floral resources, and is further threatened by the prospect of loss of access to very productive resources in 2024.

THE "MORE THAN HONEY" REPORT

The Australian Parliamentary Inquiry into the Future of the Australian Honey Bee and Pollination industries was held in 2007 with the report dated May, 2008. The subsequent report "More than Honey" recognises that billions of dollars' worth of crops that rely on honey bee pollination will be at risk if there is failure, or partial failure, of apiculture in Australia. Below are three quotes from the "More than Honey" report which for the first time in Australia closely examined the importance of this issue.

1. Current and future prospects

1.1 The Australian honey bee industry is a small but vital component of the Australian economy. While the production of honey and associated bee products represent only some $80 million per annum gross value of production, the value of European honey bees (*Apis mellifera*) to agricultural production is reckoned in terms of billions of dollars. Taking into account all plant based industries and wool, meat and dairy production, it is estimated that honey bees contribute directly to between $4 billion and $6 billion worth of agricultural production. In its submission to the inquiry, the Australian Honeybee Industry Council (AHBIC), the honey bee industry's peak body, noted that :

> Honeybee pollination provides significant value to Australian horticulture and agriculture with services being valued at $3.8 billion per annum for the 35 most important honeybee dependent crops. When other crops, including pastures such as lucerne and clover, are added this estimate becomes even larger. If honeybee pollination were to stop completely, large losses would be felt in the horticulture sector. This is because approximately 65 per cent of the horticultural and agricultural crops produced in Australia require pollination services from honeybees.

2. Foreword
   The humble honey bee is one of the most important contributors to the success of Australian agriculture. Many crop and pasture species are heavily or totally reliant on bees for pollination. Commercial prosperity within the agricultural sector requires bees. So does the food security of Australia and the world. Yet, the Australian honey bee industry faces a number of significant threats and challenges. A major challenge is resource security.

3. From List of recommendations
   The Committee recommends that the Australian Government, in conjunction with State and Territory governments, establish guidelines for beekeeper access to public lands and leasehold lands, including national parks, with a view to securing the floral resources of the Australian honey bee industry and pollination dependent industries.

Nothing relevant to secure access to previous state forest lands has changed in Queensland in the nine years since the report and the future for apiculture and pollination dependent industries is bleak.

IN CONCLUSION

Some of the losses in apicultural resources were probably inevitable as the population increased and the state developed. Some, however, could have been avoided with a better understanding of the gross value to the community of vegetation in key areas, better and properly enforced land clearing regulations and wiser land use decisions.

THE CLEARING OF THE TRAPROCK GRANITE LANDS AND THE TRANSFER OF ENORMOUS AREAS OF STATE FOREST TO NATIONAL PARKS

The vegetation of the Traprock and the Western Granite Belt lands was, until 1970, the State's most important apicultural resource with a range of eucalypt species, all of which were valuable for honey production. These included yellow box, a prolific producer of the State's most valuable general use honey. The owners of these lands after freeholding were wool growers and in their endeavours to maximise production undertook massive land / tree clearing. The reduction of this most important resource led to a major reduction of resident beekeepers in Warwick and most towns of the Darling Downs. Some had employees; we had three full time staff and casuals from time to time. While apiarist numbers were small, their loss from rural communities was another step in the rural downturn. The reserve price for wool gave this industry a period of viability for little more than a decade. Aided by more effective tree killing options, the honey bee floral resources were decimated during this period. The loss of viability after the end of the reserve price scheme resulted in a major decline in wool growing and movement of grazier families from the Traprock area.

The gross value of production from the area is now greatly reduced, but could have continued to include a significant value of apiary products had land clearing been more moderate and selective.

The transfer of enormous areas of state forest to national parks : By the year 2000 with the increases in the national park estate in the previous decade, representative areas of most bio-regions in Queensland had been secured. As well, the apiculture industry, through fruitful negotiations had maintained access to resources with a long history of managed beekeeping. All this reasoned decision making was not continued into the South East Queensland Forest Agreement, nor, as far as I am aware, into decisions into the future use of the Western Hardwood areas.

The decision to end apiculture in the most productive forests in south-east Queensland in 2024 is in contravention of the policy approved in 1997, is not based on the available science and will destroy part of the industry so critical to agriculture. While I am not involved in the timber industry, I am aware of adjustments over the years in timber harvesting and silvicultural practices that ensured the needs of wildlife conservation. I am also aware of the contribution timber milling makes to many rural communities, albeit modest when compared to more productive forests.

Governments foresee a doubling of rural output in Queensland. This will not occur by clearing more marginal lands. If the proposed increase in production occurs it will be by intensive production of high value crops, many of which will be yield dependant on effective fertilisation through honey bee pollination. This is recognised in the "More than Honey ….. " Report - and it is yet to be reflected by decisions in the Queensland Government.

LITERATURE CITED

BRIGGS. L.J. AND KEITH, D.G. 1987 : Honeybees in Australian Conserved Forests. Federal Council of Australian Apiarists' Associations (FCAAA). Revised 1996.

BOYLAND D.E. 1995 : Beekeeping in Conserved Forests - Paper presented to Queensland Beekeepers' Association (QBA) Annual Conference.

HOUSE OF REPRESENTATIVES STANDING COMMITTEE ON PRIMARY INDUSTRIES AND RESOURCES 2008 : More Than Honey the future of the Australian honey bee and pollination industries.

JOINT COMMITTEE - COMMONWEALTH AND QUEENSLAND REGIONAL FOREST STEERING COMMITTEE 1999 : South East Queensland Comprehensive Regional Assessment.

KLEINSCHMIDT G. 1986 : Graham Kleinschmidt Research Papers (Queensland Agricultural College and Queensland Beekeepers' Association).

QUEENSLAND DEPARTMENT OF THE ENVIRONMENT 1997 : Protected Area Policy Manual : General Operations Policy No. 1.10.8 : Beekeeping on Protected Areas.

OLDROYD B. ET AL LATROBE UNIVERSITY 1994 : A Survey of the Occupation of Tree Hollows by Feral Honey Bees and Regent Parrots, Wyperfield National Park, Victoria

PATON D. ADELAIDE UNIVERSITY 1990-1991 : Impacts of Commercial Numbers of Honey Bees on Flora and Fauna in Banksia Heathland in Ngarkat Conservation Reserve, South Austrlia.

ROBSON, M., MINISTER FOR ENVIRONMENT AND HERITAGE 1994. : Letter to L. Dewar, President of the Queensland Beekeepers' Association – undated – Reference No. 201486.

ROFF, C. AND BLAKE S.T. 1972 : Honey Flora of Queensland.

SEEMAN, O. 1994 - The Impact of Managed Honey Bees on Native Australian Animals and Plants – Department of Entomology, The University of Queensland.

SCHWARZ M. ET AL LATROBE UNIVERSITY 1991 – 1992 : Assessment of Competition Between Honey Bees and Native Bees, Cobboboonee State Forest, Victoria

AUTHOR PROFILE

I was born in 1939 and helped in the family apiary from age twelve, gaining basic knowledge of, and a keen interest in, these amazing insects.

I completed the Junior Certificate at Gatton College in 1954 and commenced working for my father. I continued beekeeping for 53 years.

I joined the Queensland Beekeepers' Association in 1955 and served in many industry positions including State President 1983–1986 and National President of the Federal Council of Australian Apiarists' Associations 1986–1989.

I was elected to the Board of Directors of Capilano Honey Limited in 1989 and was Chairman of Directors from 2000 to 2005.

I was awarded a Member of the Order of Australia in 1999 for services to the Apiculture Industry.

ENVIRONMENTAL ALTERATIONS IN SOUTHEAST QUEENSLAND ENDANGER THE AUSTRALIAN LUNGFISH, *NEOCERATODUS FORSTERI* (OSTEICHTHYES: DIPNOI)

KEMP, A.

Water impoundments across rivers in southeast Queensland have profound effects on the fish that live there, especially the lungfish that inhabit these reservoirs, most of which have no operating fish transfer devices that are suitable for lungfish, or no fishways at all, such as Enoggera Reservoir, Lakes Wivenhoe and Somerset in the Brisbane River system and Lake Samsonvale in the Pine River system. A population of the threatened Australian lungfish, *Neoceratodus forsteri*, lived in Enoggera Reservoir since they were first introduced there in 1896, but may now be extinct. Lungfish are endemic to the Brisbane River, and lungfish live in relatively unchanged reaches of this catchment. However, adult lungfish living in Lake Wivenhoe, and in Lake Samsonvale, have been trapped in these reservoirs since 1984 and 1976 respectively, and recruitment has ceased, perhaps because the population of fish in these reservoirs is ageing, or because the adults have poor food supplies and cannot lay viable eggs. Analysis of the gut contents and the dental structures of lungfish involved in the Lake Samsonvale and Lake Wivenhoe fish kills of 2009 and comparison with material collected between 1981 and 1990 from the Brisbane River below Lake Wivenhoe, and with specimens collected by electrofishing in Enoggera Reservoir in 1981, indicates that the adults in the fish kills of 2009 were not old, but had eaten nothing for a long time.

Key words: lungfish condition; habitat problems; environmental alteration; lack of food

Anne Kemp, Environmental Futures Centre, Griffith University, 170 Kessels Road, Nathan, Brisbane, Queensland 4111, Australia; email: a.kemp@griffith.edu.au

INTRODUCTION

The Australian lungfish, *Neoceratodus forsteri*, is endemic to three major river systems in southeast Queensland, the Mary (Gunther, 1871), the Burnett (Krefft, 1870) and the Brisbane River (Kemp & Huynen, 2014), and possibly a fourth, the Pine River (William Loh, University of Queensland, pers. comm.). All of these rivers are affected by water impoundments. Most of the surviving wild populations of the lungfish in these rivers consist of large adult fish, of uncertain age, and subadult and juvenile fish are rare or absent (Bancroft, 1913; Illidge, 1893; Brooks & Kind, 2002). Spawning ceased in parts of the Brisbane River during the drought of 2001-2008, and was affected by the subsequent flooding in the river. Spawning has occurred in the water impoundments (Kemp, 1984; Roberts et al. 2014; Espinoza et al. 2013), but recruitment may not follow the spawning events (Kemp, 2011, 2014).

One possibility to account for poor recruitment in water impoundments is the age of the adult fish trapped in these reservoirs, although the age of the lungfish in the reservoirs is not known with any certainty. Some species of fish are short lived, such as salmon, eels and lampreys, and die soon after they spawn for the first time (Patniak et al., 1994). Many bony fish, like the medaka and the guppy, display a gradual ageing process, as do most vertebrates, with slow loss of parameters like growth and reproductive capabilities (Gerking, 1957; Kishi, 2006). A third group, including basal fishes like the paddle fish and sturgeons, as well as derived fishes like many teleosts, appear to have growth processes that are difficult to determine, with some suggestions that they grow throughout life, and ageing is so slow as to be insignificant (Patniak et al., 1994). Lungfish certainly do not belong to the first group, and which of the other two groups include lungfish is not known. Although lungfish have the reputation of surviving for a long time in natural environments, nobody is quite sure how long each individual fish can live, or how long they remain capable of reproduction. To date, none of the methods of assessing age, successful or partially successful in bony fish from temperate climates (Campana, 2001), have worked for lungfish. One method of assessing age that has been published recently does not provide an accurate, verifiable age in years (James et al., 2010; Fallon et al., 2015), or stand up to critical analysis (Kemp, 2015, Kemp et

al. 2015). A more complete understanding of the population structure of the lungfish in their now remnant environments is seriously hampered because there is as yet no reliable way of assessing the ages of the lungfish in a particular population (Kemp 2015). All that is known for certain is that there are few or no juvenile fish and that recruitment has ceased in many environments, certainly in water impoundments and possibly also in most parts of the rivers that are free of regulation (Kemp, 2011, 2014).

Otoliths cannot be used to assess the age of *N. forsteri*, because otoliths have only one incremental line, even in adult fish (Retzius, 1881; Gauldie et al. 1987). Analysis of age by counting the growth layers in lungfish tooth plates provides no data on precise ages for detailed population studies, because the permanent tooth plates wear continuously throughout the life of the animal. Assessment of age based on wear and pathologies present in the tooth plates of similar size can be useful, if not completely valid as a determinant of age, with smooth wear and no pathologies suggestive of a young fish, and heavy wear with erosion of the mediolingual face and numerous carious lesions indicative of an old fish (Kemp, 2005). Wear on the tooth plates can also indicate if the fish were in fact feeding and using the tooth plates to crush or grind their food, or had no food and were grinding the tooth plates together in the absence of food.

Examination of the tooth plates of lungfish destroyed during a flood event in 2009 in Lake Wivenhoe, a reservoir on the Brisbane River, and in the creek below Lake Samsonvale, a water impoundment on the Pine River, is reported in this contribution. The material from the fish kills is compared with specimens from the Brisbane River before and soon after Lake Wivenhoe was established, and from Enoggera Reservoir where a translocated population of lungfish once lived. Analysis of the contents of the intestines and of faecal samples from the specimens is included.

MATERIALS AND METHODS

Sites of collection of material are indicated in Fig. 1.

Eleven lungfish, from the mid Brisbane River (Lowood to Fernvale), were obtained by electrofishing between 1981 and 1990, before and after Lake Wivenhoe was built, but while the river was still in good condition. Eleven adults from Enoggera Reservoir were collected by electrofishing in 1981. All of this material was collected for other projects, in early summer, and skeletal and dental material derived from these fish was used for this research. Small tooth plates collected at the same time from the Brisbane River (Kemp, 2005) were omitted, because there is no comparable material of small lungfish from other localities. Any tooth plates from the river or the reservoir with extreme pathologies, such as hyperplasia or parasitic infection (Kemp, 2005) were also excluded from this analysis.

Comparative material from adult lungfish in the Brisbane River from a time equivalent to the material collected from the head of Lake Wivenhoe in 2009 was not obtained for this project, for two reasons. Lungfish are threatened, and specimens should not be obtained specifically for a project. More importantly, the lungfish in the Brisbane River in 2009 had just passed through eight years of severe drought. Snails and clams on which lungfish feed almost exclusively in the wild (Kemp, 1987) disappeared from the river during this time, and have not yet recovered. The lungfish would have been unable to feed, and this would have affected their dentition.

Twelve large adult lungfish came from at least 70 dead specimens found among rocks below the wall of Lake Somerset close to the headwaters of Lake Wivenhoe, on the Brisbane River, in winter, after heavy rain in July 2009. These fish came from Lake Wivenhoe, and not from Lake Somerset, which did not overflow at this time. They were trying to swim upstream during the flood. Reports from staff at the reservoir claimed that it was impossible to turn them back. Some were rescued, and others died when the water receded and left them exposed among the rocks. Eight fish, also adults, were collected from the area below the wall of the dam at Lake Samsonvale (Pine River catchment) during a flood event in early summer, when they were washed over the wall of the reservoir (October, 2009). Most of these were left exposed on the bank when the floods went down. A ninth fish was donated by a conservation society who examined the surroundings of the spillway pool after the flood, and found many more dead fish, also washed over the wall of the dam.

Body condition of the fish was assessed using weight and length data, where possible, and by post-mortem observation of tissues and organs, including the presence of ferritin laden oil in the tissues. Diets were analysed from faecal samples, when available, and from intestinal contents in dead fish. After weighing

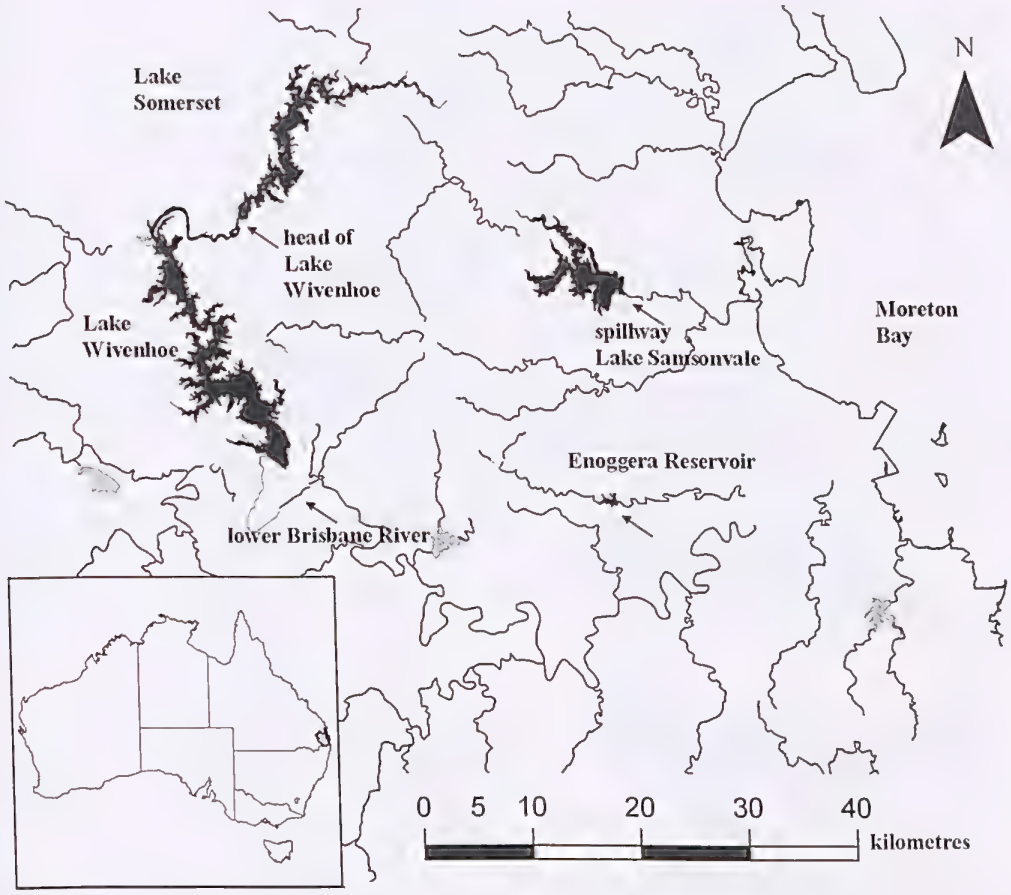


FIG. 1. Map of southeast Queensland, showing Lake Wivenhoe and Lake Somerset on the Brisbane River, and Lake Samsonvale on the Pine River, and Enoggera Reservoir, on a tributary of the Brisbane River. Arrows indicate sites of collection of material.

and measuring the fish, and assessing gut contents, skeletal and dental material, including 5 specimens from the Samsonvale fish kill, and six from Lake Wivenhoe, were dried and prepared by exposing the dead fish to dermestid beetles.

Lengths of the tooth plates from all four sources were measured, using digital calipers with a resolution of 0.01 mm, as well as the depth of the cleft on the occlusal surface between ridge 2 and 3, 2 mm from the medial margin of the tooth plate. The depth of this cleft reflects the amount of wear on the occlusal surface and was chosen because it is the deepest of the five or six clefts between ridges, and is straight. In most cases both upper and lower tooth plates were available from each fish, and occasionally only one or two tooth plates. Data from upper and lower tooth plates was kept separate.

Certain conditions of the tooth plates and attached bone that suggest heavy usage and age were recorded for each specimen (Kemp, 2005). Spur and step wear, which produces a high spur on the posterior margin of the lower tooth plate and a step on the corresponding upper tooth plate, was noted, as well as attrition, or wear of the tooth plates with no food present, showing that the fish had little to eat. Extreme erosion of dental tissue with carious lesions suggests that the environment is poor (Kemp, 2005), and osteopenia indicates an inadequate diet, as well as age of the fish.

RESULTS

BRISBANE RIVER LUNGFISH

Body condition Fish from the Brisbane River collected between 1974 and 1990 before much alteration in the river were in reasonable condition, and tissues were laden with ferritin rich oil, as is usual in wild lungfish. Skins were clear, and abdomens plump. There were no externally obvious pathologies, and colour, dark brown on the dorsal surface and pink on the belly, was normal. Scale cover was complete. No length and weight data are available for this historical collection.

The diet Intestinal contents of adult lungfish from the Brisbane River included large quantities of plant and animal material, suggesting that the fish are omnivorous (Spencer, 1892). However, the plant material consisted mostly of filamentous algae (*Rhizoclonium*), with occasional fragments of *Myriophyllum*, none affected by chewing. Broken shells of snails, *Thiara* (*Plotiopsis*) *balonnensis*, and small clams, *Corbicula australis*, predominated among the animal residues, with the occasional scale from a small fish, and fragments of a shrimp carapace. This indicates that the fish in River environments obtain their nutrients almost entirely from snails and clams. The intestines also contained masses of sand, a result of the suctorial feeding habits of the adult lungfish. Faecal samples contained a similar mixture. Plant material in the faeces had not been digested, and could still be identified. The fish were collected in early summer. Observations of the river environment indicate that both plant and animal food was plentiful at this time (Davie, Stock and Low Choy, 1990).

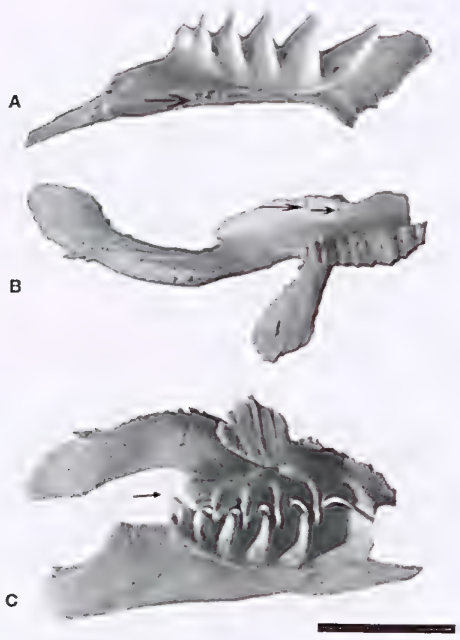


FIG. 2. The dentition of fish from the Brisbane River. A. Occlusal view of a lower tooth plate, QM I 26008, showing smooth occlusal surface, rounded ridge crests and smooth furrows between the ridges. The bone shows osteopenia (arrowed). B. Upper tooth plate, QM I 26016, in mediolingual view, with furrows that are not incised to the mediolingual face. There are small carious lesions on the mediolingual face (arrowed) C. Labial view of upper and lower tooth plates in occlusion, QM I 26014, showing spur on the lower tooth plate (arrowed) and corresponding step on the upper. Scale bars = 2 cm.

The dentition Tooth plates of lungfish from the Brisbane River have a smooth occlusal surface, rounded ridge crests and shallow rounded furrows in the clefts between the ridges (Fig. 2A, B). There is little or no incision of the medial margin of the tooth plate (Fig. 2B). This wear pattern suggests light grinding abrasion, with sub-terminal rotational grinding of food items.

Measurements of medial wear taken 2 mm from the medial surface indicate that average depth of the furrows in the upper tooth plate was 0.8 mm, and in the lower tooth plates 0.9 mm. Wear of the dentition in fish from this river was light (Fig. 3A, B) and indicates minimal chewing of food items, sufficient to break the shells of snails or clams, and prepare the ingested animals for digestion in the anterior sac and spiral valve of the intestine.

One specimen had a small exostosis on the medial face, and two specimens have malocclusion. Spur and step wear is present in eight out of 11 specimens (Fig. 2C), and two have osteopenia, one quite severe (Fig. 2A). All have mild erosion of the mediolingual face (Fig. 2A), and five out of eleven specimens have small carious lesions. None of the tooth plates have hyperplasia. The size and condition of the tooth plates indicates that the dental material came from large adult fish, and some of the changes, such as caries, erosion osteopenia and spur and step wear, suggest age.

ENOGGERA RESERVOIR LUNGFISH

Body condition On capture, the eleven living fish

were in good condition, large and heavy with plump abdomens. Lengths ranged from 98 cm to 114 cm, and weights ranged from 8kg to 11kg. Tissues were laden with ferritin rich oil. There were no externally obvious pathologies. Skins were uninjured and scale cover complete. Colour of the fish was normal, dark brown dorsally and pink ventrally. Collections were made in early summer.

The diet Lungfish in Enoggera Reservoir had a restricted diet by comparison with Brisbane River fish. Intestinal and faecal samples included leaves of *Hydrilla verticillata* and the broken shells of small freshwater snails, with a few fragments of shrimp carapaces. Food in this reservoir was not abundant, nor varied, at the time the fish were collected in early summer, nor is food ever particularly plentiful in this environment (Kemp 2005). Most of the plants that are found in Enoggera Reservoir occur around the margin of the lake, such as *Urochloa mutica* and *Myriophyllum*, neither of which appeared in the intestinal contents or faeces. *Hydrilla verticillata* also grows in shallow water around the shore, and shelters small snails and shrimps. Plant material had not been masticated and was not digested.

The dentition All of the tooth plates from Enoggera Reservoir came from large adult fish. The occlusal surface is incised from the labial to the medial margin (Fig. 4A, B) in every specimen. Slight hyperplasia of individual ridge crests occurred in nine of the specimens, with a correspondingly deep furrow in the opposing tooth plate. Erosion of dental tissue, usually with deeper carious lesions exposing the pulp cavity, was found in every single tooth plate, along the medial face (Fig. 4A). One has small traumatic lesions on the labial face of every ridge and others have similar lesions on single ridges. Seven of the specimens showed spur and step wear and the attached bones of the jaws of every tooth plate were affected by osteopenia. All of the tooth plates were severely worn (Fig. 4B).

Tooth plates from Enoggera Reservoir have high, faceted ridge crests separated by deep furrows,

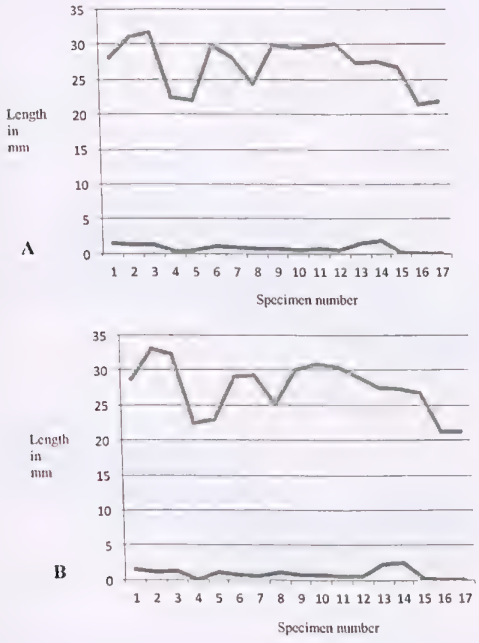


FIG. 3. Plot of tooth plate length (upper line) and depth of the furrow at the medial margin of the tooth plate (lower line) in material from the Brisbane River. Wear on these tooth plates is light.

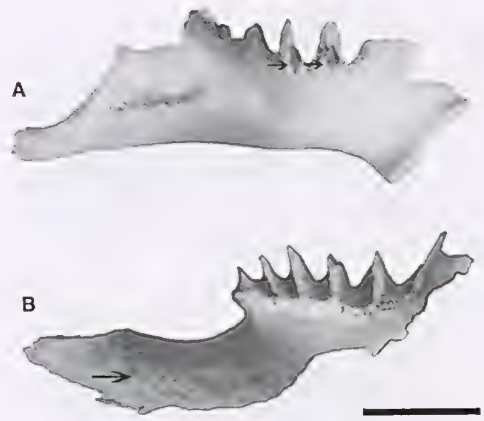


FIG. 4. The dentition of fish from Enoggera Reservoir. A. A lower tooth plate, AN88-107, in medial view, showing deeply incised furrows between the ridges and carious lesions (arrowed) along the medial face. B. An upper tooth plate, QM I 26018, in occlusal view showing deeply incised furrows and supporting bone with osteopenia (arrowed). Scale bars = 2cm.

with an average depth of 4 mm on the medial face of the upper tooth plates and 4.2 mm on the lowers (Fig. 5A, B). Wear on every tooth plate from Enoggera Reservoir is extreme.

LAKE SAMSONVALE

Body condition Body condition in the lungfish from Lake Samsonvale was poor, and the fish were thin. The fish were washed over the reservoir wall in spring during heavy rain in 2009. The dorsal surface was a dull brown, and the belly a dull pale yellow. All were adult fish, ranging from 3-9 kg in weight and 85-120 cm in length. No ferritin rich oil was visible in the tissues. Eight fish had extensive bruising on the belly, and the bruises extended into the underlying skin and muscle. On several fish, large areas of scales have been removed. Examination of the remaining scales at the edge of these areas showed that damage to these scales had been caused by abrasion against a rough surface. Skin had also been removed from the snout and the mandible of most fish, in places where scales are absent. One fish had evidence of healed trauma to the pectoral fins.

Diet Post mortem examination of nine fish from the Lake Samsonvale spillway pool revealed traces of filamentous algae in the rectum. Several fish had fragments of tree leaves in the posterior intestine. The anterior sacs and the anterior intestine of all the fish were empty and any plant material in the gut was undigested. The fish kill in this system occurred in early summer, when food items are present in most environments. The fish kill was catastrophic, and fish would not have survived long before the water receded and left them stranded on the banks.

The dentition Medial erosion with caries is present in most of the tooth plates (Fig. 6 A, B). Three out of five specimens show spur and step wear, and one has malocclusion in one jaw. Wear in four of the five is smooth, and medial furrows are slight or absent, with an average depth of 0.3 mm in the upper tooth plates and 0.1 mm in the lower (Fig. 7A, B), indicating that the fish had not been chewing food. Attrition is present in four out of five specimens.

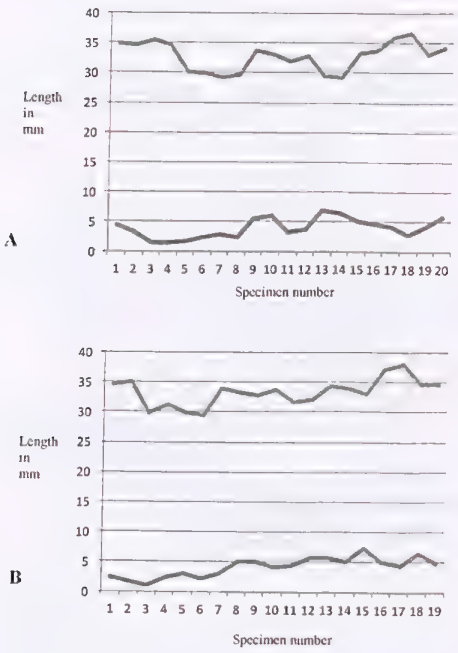


FIG. 5. Plot of tooth plate length (upper line) and depth of the furrow at the medial margin of the tooth plate (lower line) in material from Enoggera Reservoir. Wear on these tooth plates is usually extreme.

FIG. 6. Tooth plates from the fish killed on the Lake Samsonvale spillway. A. Lower tooth plate, AN09-104, in medial view showing healthy bone and small carious lesions. B. Upper tooth plate, AN 09-106, showing flat occlusal surface and healthy bone. Scale bars = 2 cm.

HEAD OF LAKE WIVENHOE

Body condition All of the specimens collected during the midwinter flooding event from the head of Lake Wivenhoe were large adult fish, ranging in weight from 7-16kg and 90-130cm in length. Body condition appears reasonable, but the tissues had little ferritin stained oil. Gonads were developing, preparatory to the spawning season in a few months time. All of the fish show significant bruising on the body, with broken and missing scales. Apart from the bruising, colour was normal, dark brown on the back and pink on the belly. One fish had a broken jaw, and another had fractured skull bones. The fish died of trauma or exposure among the rocks at the head of the reservoir.

Post mortem examinations were carried out on nine of the twelve fish collected. The anterior sac and the spiral valve of the intestine in all of these fish contained no food in the process of digestion. Guts of most of the fish had blackened blood clots in the anterior sac, either the result of bleeding into the gut or the swallowing of blood from the oral cavity. Seven of the fish had discoloured fragments of filamentous algae in the posterior intestine, one had nothing, and one had fragments of *Corbicula* shells as well as filamentous algae. The fish died in midwinter, at a time when food items in the environment would have been reduced.

The dentition The tooth plates from Lake Wivenhoe fall within the large size class and all come from adult fish. Erosion on the medial face is slight and few specimens have carious lesions (Fig. 8A, B). One fish has a large deficiency in an upper tooth plate, with slight hyperplasia in the opposing lower. Three have spur and step wear, severe in one specimen (Fig. 8A), and the bones of four fish show osteopenia.

The occlusal surfaces of the tooth plates from six specimens collected from the head of Lake Wivenhoe are worn smooth and flat, with shallow furrows, an average of 0.6 mm deep on the medial face of both upper and lower tooth plates (Fig. 9A, B). The shallow medial and labial furrows indicate minimal chewing.

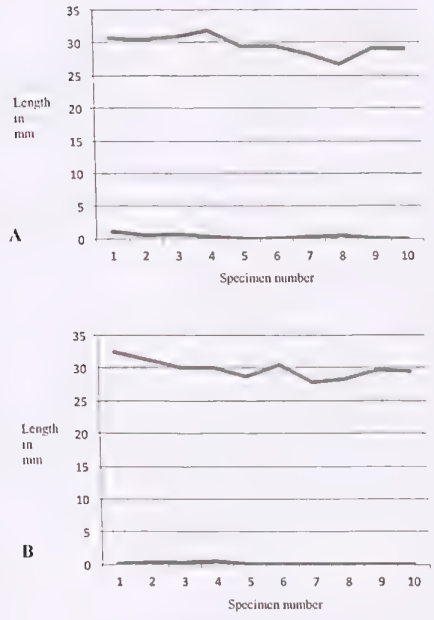


FIG. 7. Plot of tooth plate length (upper line) and depth of the furrow at the medial margin of the tooth plate (lower line) in material from the Lake Samsonvale fish kill. Wear on these tooth plates is negligible.

FIG. 8. Tooth plates from the fish killed at the head of Lake Wivenhoe. A. Lower tooth plate, AN 09-112, in medial view, showing a pronounced spur and carious lesions (arrowed) on the medial face. B. Upper tooth plate, AN 09-115, in occlusal view with flat occlusal surface. Both bones show osteopenia (arrowed). Scale bars = 2 cm.

DISCUSSION

This study is based on adult lungfish from the Brisbane River, at the time a free flowing river environment, from Enoggera Reservoir, a long established water impoundment and from two reservoirs built more recently, one, Lake Wivenhoe, completed in 1984 and the other, Lake Samsonvale, finished in 1976. None of the three water impoundments have fishways to allow fish to move safely from the water impoundment to the river or back again.

The statutory water authority that has responsibility for the reservoirs of southeast Queensland, SEQWater, monitors lungfish populations in the area, and has asked me to include the following statement in my publications.

"In response to the 2009 accidental lungfish deaths in South East Queensland dams, SEQWater developed the first Lungfish Management Program by a water authority in Australia. SEQWater prepared a detailed post flood response plan for all three gated dam sites (Wivenhoe, Somerset, North Pine) that requires, amongst many things, rangers to undertake detailed inspections of spillways immediately after flood gate operations cease, recover any stranded lungfish and place them in permanent water. In addition they record any accidental fish deaths. SEQWater has also tested a range of post flood release strategies to reduce the risk of fish stranding at spillways. They have also implemented improved communication processes to alert in advance of potential fish stranding incidents, recording of incidents and reporting to the appropriate authorities when required. Extensive civil works in high risk areas below dams to reduce the risk of fish damage and stranding during and post flood releases have been undertaken, and specialised equipment to assist in large scale lungfish recovery and research efforts has been purchased."

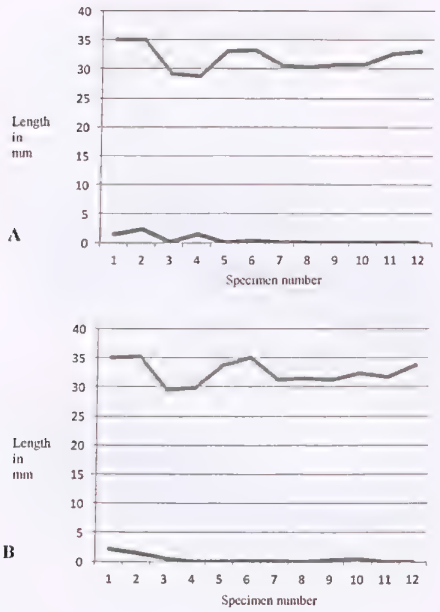


FIG. 9. Plot of tooth plate length (upper line) and depth of the furrow at the medial margin of the tooth plate (lower line) in material from the fish kill at the head of Lake Wivenhoe. Wear on these tooth plates is light or insignificant.

Lungfish are endemic to the Brisbane River (Kemp and Huynen, 2014). Some fish collected from the Mary River were placed in Enoggera Reservoir, which had no natural population of lungfish (O'Connor, 1897). Actively spawning populations were present in the Brisbane River at least until the drought of 2001-2008, and possible extinction has followed the loss of spawning habitat in Enoggera Reservoir in 1974 when water hyacinth was removed from the reservoir (Kemp, 2011). Lungfish have spawned at least once in Lake Wivenhoe (Kemp, 2011, 2014; Roberts et al., 2014) and spawn frequently in Lake Samsonvale (Kemp, 2014). However, no young have apparently been recruited to the adult population of either water impoundment in recent years. All of the hatchling lungfish were abnormal, in laboratory reared fish and in specimens collected from the Lakes and not reared in the laboratory. All died.

Reasons for the lack of recruitment of young fish in water impoundments and possible also in the rivers are not known with certainty, although it is probable that lack of appropriate nutrition causes the adults to lay poor quality eggs that do not develop normally (Kemp, 2011, 2014), as happens with wild fish populations in North America in similar situations (Fuiman et al., 2013; Furuita et al., 2003; Peleteiro et al., 1995). Other suggested reasons include lack of genetic diversity (Frentiu et al., 2001; Hughes et al., 2015), pollution, or the age of the parent fish. Genetic diversity is known to be low (Frentiu, et al., 2001; Hughes et al., 2015; Lissone, 2003, Lissone et al., 2001) and has been low for a long time, but lungfish have survived. Pollution is unlikely to cause a suite of similar aberrations in developing young when the

possible pollutants to which the fish may be exposed vary from one environment to another. This leaves diet of the parent fish, and their ages, as possible causes of the lack of recruitment.

Lengths of the tooth plates collected from the River and the three reservoirs are within the range for fully grown adult lungfish. The occlusal surface of the tooth plates are marked by furrows created by normal wear, deep furrows along the labial face of the tooth plate and furrows of variable depth along the medial face. Labial furrows, the result of the way in which the tooth plates form and lock against each other, are always present and have no significance for diet or age. Medial furrows are formed when the tooth plates wear against each other and the depth is an indication of how much the dentition has been used, and for how long. They are deep in reservoir fish, shallow in River fish and also shallow or insignificant in Lake Wivenhoe fish. Medial furrows are all negligible in fish from Lake Samsonvale.

The population of fish in the mid Brisbane River at the time the samples were collected was actively spawning and recruiting young to the population (Kemp, 1996, 2005). Fish from Enoggera Reservoir were all of an advanced age, and recruitment had ceased in this water impoundment in 1974, some years before the specimens in this study were collected (Kemp, 2005). In Lake Wivenhoe and Lake Samsonvale, all specimens came from adult fish, killed during a flood event, and probably derived from the population trapped in the water impoundments when the reservoirs were built, 1976 in the case of Lake Samsonvale and 1984 for Lake Wivenhoe. None of the fish from the fish kills were subadult or juvenile. By any estimate of years since Lake Wivenhoe and Lake Samsonvale were built these fish are likely to be, respectively, up to 40 and 32 years old at least, plus their ages when the reservoirs were completed. Although Lake Wivenhoe could have received recruits to the population from the Upper Brisbane River, this would not have happened in Lake Samsonvale, where the river flowing into the reservoir is small and unlikely to have actively spawning and recruiting lungfish able to maintain the population in the water impoundment.

The diet of wild lungfish in a natural habitat is limited (Spencer, 1892; Kemp, 1987). In the adult fish, intestinal contents include masses of filamentous algae as well as small aquatic snails (*Thiara balonnensis*) and basket clams (*Corbicula australis*). Plant material in the intestine has not been masticated and is not digested, and this suggests that Spencer (1892) was correct in assuming that the only nutrition derived from the plant material came from microscopic fauna and flora adhering to the leaves and filaments of algae. Hatchling lungfish are essentially carnivorous, ingesting small invertebrates, and perhaps the occasional strand of filamentous algae (Kemp, 1996), which is not digested. The adults are also effectively carnivorous. The molluscs, a major part of the diet of adult lungfish in the wild, provide the lungfish with volatile fatty acids, originally derived from algae in the diet of snails and clams. Volatile fatty acids are required for the production of healthy eggs (Fuiman et al., 2013; Furuita et al., 2003; Peleteiro et al., 1995).

Intestinal contents are influenced by season. Most of the specimens were collected in early summer and would have ingested food if any had been available. River fish and fish from Enoggera Reservoir had been feeding, but fish from Lake Samsonvale, killed in a catastrophic event, had empty intestines. It is unlikely that food present in the gut before they went over the wall would have been digested before the fish died and were left on the dry banks. Fish from the head of Lake Wivenhoe were collected in winter when food supplies would have been limited, as snails and clams die back in winter. One remarkable aspect of the present analysis is that unless conditions are really poor, as they are in Lake Samsonvale and in the creek below the reservoir wall, with poor water quality and little available food, lungfish look plump and healthy. Further, wear on the dentition is continual, and not merely a feature of ingesting food.

Body condition in River and Enoggera fish was good, and they had been able to find food. Despite having no food in the intestines, fish from the head of Lake Wivenhoe appeared to be in at least adequate condition. Lake Samsonvale fish were in poor condition, and had been so for a long time. Condition of the medial furrows on the tooth plates of these fish suggests that the Wivenhoe and Samsonvale fish had not eaten for a long time, a result supported by the emptiness of the intestines in fish from both sites, and the lack of ferritin rich oil in the tissues of fish from water impoundments. Wild lungfish should have masses of oil in the tissues. Laboratory reared lungfish, which do not eat a natural diet, or fish kept under poor conditions, have little ferritin, and any oil present is pale yellow, green or absent.

Enoggera fish have tooth plates that suggest heavy crushing abrasion and a limited and harsh diet for a long time, with deep furrows, and numerous severe pathologies, such as severe erosion, caries, and osteopenia. Brisbane River fish, at the time of collection, appear to have had a reasonable diet with plentiful food that did not require harsh grinding. In any case, snails and clams are broken but not masticated before being swallowed, and easily identified in the intestinal contents or in the faeces. Pathologies on the tooth plates are not severe. Specimens derived from the fish kills suggest that these fish had little to eat, although pathology is not extensive. Age and diet related characters like osteopenia and spur and step wear are similar to those of Brisbane River fish collected much earlier. Comparison with dental characters from Brisbane River fish collected before Lake Wivenhoe was built, and Enoggera Reservoir fish after clearing of the hyacinth and removal of spawning sites suggests two things - the Lake Samsonvale and Lake Wivenhoe fish had little food, and no recruitment, but were not as senescent as the fish from Enoggera Reservoir. If the fish from the water impoundments had been old, the tooth plates would have shown heavier wear and more severe pathology.

The adults of Lake Samsonvale and Lake Wivenhoe, affected by the fish kills, were not particularly old fish. Most have smoothly worn tooth plates, characteristic of attrition. The failure of recruitment recorded in 2009 in Lake Wivenhoe and in 2010 and later years in Lake Samsonvale (Kemp, 2011, 2014) cannot be explained by saying that the population is ageing, and therefore cannot be expected produce viable spawn. These fish had eaten little food for a long time. This would have affected the production of eggs and may have resulted in the failure of recruitment. An inadequate diet is a consequence of environmental alteration, and is likely to have a severe effect on the survival of natural populations of the Australian lungfish.

ACKNOWLEDGEMENTS

Fish were obtained with the permission of the Queensland Government Department of Primary Industries and Fisheries, permit no. 160372 and the Animal Ethics Committee of Queensland University, permit no. CMS/350/09. The author received no funding from any public source for this research. Ryan Day and William Loh collected fish from the head of Lake Wivenhoe; Owen Kelly collected fish from the Brisbane River; Ian Johnston collected the Enoggera fish; officials of SEQWater and local conservationists provided the fish from Lake Samsonvale. Steve Mallett carried out the post mortems of fish from Lake Wivenhoe and Lake Samsonvale. Mike Foster from SEQWater provided the information on the management plan for lungfish in water impoundments. Assistance from all sources is acknowledged with many thanks.

LITERATURE CITED

BANCROFT, T. L. 1913. On an easy and certain method of hatching *Ceratodus* ova. Proceedings of the Royal Society, Queensland 25:1-3.

BROOKS, S. G. & KIND, P. K. 2002. Ecology and demography of the Queensland lungfish (*Neoceratodus forsteri*) in the Burnett River, Queensland. Report, Queensland DPI, Brisbane.

CAMPANA, S. E. 2001. Accuracy, precision and quality control in age determination, including a review of the use and abuse of age validation methods. Journal of Fish Biology 59:197–242.

DAVIE, P, STOCK, E and LOW CHOY D. 1990. The Brisbane River: a source book for the future. Australian Littoral Society and the Queensland Museum.

ESPINOZA, T., MARSHALL, S. & MCDOUGALL, A. 2013. Spawning of the endangered Australian lungfish (*Neoceratodus forsteri*) in a heavily regulated river: a pulse for life. River Research and Applications 29:1215-1225.

FALLON, S. J., MCDOUGALL, A., ESPINOZA, T., ROBERTS, D., BROOKS, S. & KIND, P. 2015. Updated methods to age the Australian lungfish: reply to KEMP 2015. Radiocarbon 57:195-197.

FRENTUI, F. D., OVENDEN, J. R. & STREET, R. 2001. Australian lungfish (*Neoceratodus forsteri*: Dipnoi) have low genetic variation at allozyme and mitochondrial DNA loci: a conservation alert? Conservation Genetics 2:63-67.

FUIMAN, L. A. & FALK, C. K. 2013. Batch spawning facilitates transfer of an essential nutrient from diet to eggs in a marine fish. Biology Letters 9:20130593.

FURUITA, H., OHTA, H., UNUMA, T., TANAKA, H., KAGAWA, H., SUZUKI, N. & YAMAMOTO, N. 2003. Biochemical composition of eggs in relation to egg quality in the Japanese eel, *Anguilla japonica*. Fish Physiology and Biochemistry 29:37–46.

GAULDIE, J. W., DUNLOP, D. & TSE, J. 1986. The remarkable lungfish otolith. New Zealand Journal of Marine and Freshwater Research 20:81-92.

GERKING, S. D. 1957. Evidences of ageing in natural populations of fishes. Gerontologia 1:287-305.

GUNTHER, A. 1871. Description of *Ceratodus*, a genus of ganoid fishes, recently discovered in rivers of Queensland, Australia. Transactions of the Royal Society of London 161:511-571.

HUGHES, J. M., SCHMIDT, D. J., HUEY, J. A., REAL, K. M., ESPINOZA, T., McDOUGALL, A., KIND, P. K., BROOKS, S. & ROBERTS D. T. 2015. Extremely Low Microsatellite Diversity but Distinct Population Structure in a Long-Lived Threatened Species, the Australian Lungfish, *Neoceratodus forsteri* (Dipnoi). PLoS ONE 10(4):e0121858. doi:10.1371/journal.pone.0121858.

ILLIDGE, T. 1893. On *Ceratodus forsteri*. Proceedings of the Royal Society, Queensland 10:40-44.

JAMES, K. M., FALLON, S. J., McDOUGALL, A., ESPINOZA, T. & BROADFOOT C. 2010. Assessing the potential for radiocarbon dating the scales of Australian lungfish (*Neoceratodus forsteri*). Radiocarbon 52:1084-1089.

KEMP, A. 1987. The Biology of the Australian lungfish, *Neoceratodus forsteri*. Journal of Morphology, supplement 1:181-198.

KEMP, A. 1996. The role of epidermal cilia in development of the Australian lungfish, *Neoceratodus forsteri* (Osteichthyes: Dipnoi). Journal of Morphology 228:203-221.

KEMP, A. 2005. New insights into ancient environments using dental characters in Australian Cenozoic Lungfish. Alcheringa 29:123-149.

KEMP, A. 2011. Comparison of embryological development in the threatened Australian lungfish *Neoceratodus forsteri* from two sites in a Queensland River system. Endangered Species Research 15:87-101.

KEMP, A. 2014. Abnormal development in embryos and hatchlings of the Australian lungfish, *Neoceratodus forsteri*, from two reservoirs in southeast Queensland. Australian Journal of Zoology 62:63-79.

KEMP, A. 2015. Assessing the Age of Wild Lungfish. Comments on JAMES et al. (2010). Radiocarbon 157:193-194.

KEMP, A., HEASLOP, M. & CARR, A. 2015. Scale Structure in the Australian Lungfish, *Neoceratodus forsteri* (Osteichthyes: Dipnoi). Journal of Morphology 276:1137-1145.

KEMP, A. & HUYNEN, L. 2014. Occurrence of lungfish in the Brisbane River, Queensland, Australia dates back to 3850 yr BP. Journal of Archaeological Research 52:184-188.

KREFFT, G. 1870. Description of a gigantic amphibian allied to the genus *Lepidosiren*, from the Wide-Bay District, Queensland. Proceedings of the Zoological Society of London 1870:221-224.

KISHI, S. 2006. Functional ageing and gradual senescence in zebrafish. Annals of the New York Academy of Sciences 1019:521-526.

LISSONE, I. 2003. Conservation genetics and the Australian lungfish *Neoceratodus forsteri* (Krefft 1870); a spatio-temporal study of population structure. MScThesis, University of the Sunshine Coast, Sippy Downs, Queensland.

LISSONE, I., SHAPCOTT, A. & OVENDEN, J. 2001. The use of RAFs enables determination of genetic structure within and among catchments in the Australian lungfish *Neoceratodus forsteri*. Abstract, Genetics Society of Australia, Melbourne.

O'CONNOR D (1897) Report on preservation of *Ceratodus*. Proceedings of the Royal Society of Queensland 12:101-102.

PATNIAK, B. K., MAHAPATRO, N. JENA, B. S. 1994. Ageing in fishes. Gerontology 40:113-132.

PELETEIRO, J. B., LAVENS, P., RODRIGUEZ-OJEA, G., INGLESIAS, J. 1995. Relationship between egg quality and fatty acid content of various turbot broodstocks (*Scophthalmus maximus* L). ICES Marine Sciences Symposium 201:51–56.

RETZIUS, G. 1881. Das Gehörorgan der Wirbelthiere. Morphologisch-histologische Studien. I. Das Gehörorgan der Fische und Amphibien. – (Centraldruckerei: Stockholm.) 222 pp.

ROBERTS, D. T., MALLETT, S., KRÜCK, N. C., LOH, W. & TIBBETTS, I. 2014. Spawning activity of the Australian lungfish *Neoceratodus forsteri* in an impoundment. Journal of Fish Biology 84:163–177.

SPENCER, W. B. 1892. Note on the habits of *Ceratodus forsteri*. Proceedings of the Royal Society of Victoria 4:81-84.

AUTHOR PROFILE

Anne Kemp was educated in Scotland (Edinburgh University) and has spent most of her adult life in Queensland. She has worked with the Australian lungfish since 1969, mostly on the development of the embryos, hatchlings and juveniles. She is currently an adjunct Associate Professor in the Environmental Futures Institute at Griffith University.

ENVIRONMENTAL STUDIES AT GRIFFITH UNIVERSITY: A BRIEF HISTORY OF THE FOUNDATION YEARS

ROSE C.W., ARTHINGTON, A.H., CONNELL D.W., & RICKSON, R.E.

INTRODUCTION

Griffith University was formally founded in 1971 without being under the patronage of another University, which had been the case for James Cook University, which commenced with strong links to the University of Queensland. A reason for this decision of government was recognition that the patronage style of development was likely to inhibit innovation in the new institution. The Interim Council, chaired by Sir Theodore Bray, played a vital role by accepting the primary importance of university education as assisting the development of a "liberal mind". Achievement of this broad goal was to be aided by exposing undergraduates to knowledge across the "Two Cultures" described by C.P. Snow (1959). This concept challenged the common philosophy and organisation of Australian and British universities at the time.

The initial Griffith approach, as described by Topley and Willett (1976), (Willett being the initial Vice-Chancellor), was to design its primary educational units to address a set of problems or issues that are perceived to exist in the world external to universities. The expectation was that this outward-looking focus would result in interdisciplinary "schools", in which staff and students would focus on "real-world" complexities. This objective was supported by the initial appointment of Professors Rose (as Chairman of Australian Environmental Studies) and Brownlea, both of whom had complementary interdisciplinary problem-oriented experience outside of universities. Providing adequate conceptual and analytical tools to deal with real-world complexities, typified by environmental issues, would of course be expected to require access to knowledge commonly expressed in disciplinary terms.

Griffith opened its doors to teaching in 1975, introducing Australia's first degree in environmental science. The concept of developing a School, initially named Australian Environmental Studies, to be one of the initial four Schools for the newly-established Griffith University, came from the initiative of Sir Theodore Bray, who was appointed Chairman of the Interim Council of the University in about 1970. Bray's inspiration came from overseas visits encouraged by members of the Interim Council, in particular Mr John Topley, Secretary to the Council, and later Registrar of Griffith University (Quirke 1996). Bray was impressed by what he saw of developments in environmental concerns in both the USA and Europe, and of environmental studies programs in USA and UK universities (e.g. Sussex University). He had support for his novel idea from at least one Council member, Professor Mason from Macquarie University. Nevertheless the initiative was regarded as a "brave decision" at the time, and was received with scepticism in some quarters.

This brief review will focus on the first five years of the School of Australian Environmental Studies (AES) which has subsequently seen very considerable growth, developing and changing as it must in response to changing issues, understanding, demands and opportunities. We sketch the underlying concepts and structure of the foundation and subsequent years in the Bachelor of Environmental Studies Degree, and provide examples of the research and post-graduate training programs that began to emerge and contribute to the environmental challenges of the times.

CONTEXT, CONCEPTS AND PLANNING

Griffith was planned and began teaching in the 1970s, a decade of unprecedented social and political change. Early documentation developed on the remit for the new environmental School was understandably rather vague, and did not directly address the social and political environmental concerns which were beginning to emerge in Queensland at the time. One concern which attracted international, national and local attention was protection of the Great Barrier Reef from oil exploration and mining (Connell 1971). The actions of two NGOs, the Wildlife Preservation Society and the Queensland Littoral Society, culminated in the initiation of the Royal Commission into Oil Drilling on the Great Barrier Reef, and later the formation of the Australian Institute for Marine Science. A great deal of media attention on the reef and other environmental issues (water pollution, habitat destruction, fish kills,

wildlife conservation) demonstrated that scientific research was lacking and there was limited knowledge regarding environmental management techniques and solutions. Threats to the Reef, and other conservation issues, served to focus public and media attention on environmental management as a scientific matter which needed attention. Most environmental issues of the time required specific research directed towards the Australian environment, since answers were not readily apparent from research elsewhere.

The name 'Australian' in the School's title was seen as a geographical locator and not to be limiting or exclusionary in its range of interests. Environmental Studies at University level was understood as an area of learning, education, research and community engagement involving communication of the knowledge necessary to understand, and hopefully anticipate, the full consequences of human activities which have an impact on the natural world, and through that on the public or common good, such as on human health and wellbeing. Further implications of the term included avoidance of environmental destruction and impact, adopting better management (of natural resources for example), and by innovation, such as the use of renewables and recycling, all in the context of a carbon-constrained world.

The term "Environmental Studies" later became to be used in different ways, for example to describe investigations required before a resource developer, or an industrial firm, could implement an activity deemed to have possible significant impact on the common good. This use of the term is often referred to as 'environmental impact analysis', which was expanded in focus to include social impact assessment of development (Lane et al. 2003).

Reflecting the extensive nature of the issues involved, Environmental Studies at Griffith was understood as essentially interdisciplinary. It therefore interacted with, contributed to and drew on the many sciences which are involved in understanding this earth, and its life-sustaining potentiality. The founding scholars were also aware of the vital roles played by socio-economic and policy factors in affecting the role of human activity in modifying and utilizing the resources of this earth-home which we share.

ON INTERDISCIPLINARITY AND ENVIRONMENTAL STUDIES

It is easy to argue that environmental problems have many rather than a single dimension requiring inquiry if we are to understand the issues in any complete manner, with the possibility of improving practice. Certainly dealing with an issue such as climate change, land use and soil erosion, chemical pollution, biodiversity loss, social and economic inequality, or industrial pollution control requires the work of many rather than a single or a few disciplines. The promise of interdisciplinary work is to bring scholars and researchers from diverse disciplines together to focus their theory and research on common problems. According to the Editors of Nature (2015) an interdisciplinary approach should drive people to ask questions and solve problems, especially those that have proved unwilling to yield to conventional approaches.

A university, a research institute or centre committing itself to interdisciplinary study is entrusting itself to build and institutionally embed a "culture of interdisciplinarity". If accepted by any group or organization, then social and professional relations among individuals across disciplines are frequent and routine rather than exceptional, increasingly easy and enjoyable, and intellectually fruitful. Whilst personal relationships are always important in collaborative work, they can be difficult to establish and sustain in interdisciplinary contexts unless partners exercise considerable empathy, patience, and interpersonal trust. Ease of contact is also important since unless collaborators are in close proximity to each other, fostering the discussions needed to establish interdisciplinary relations is hindered.

In common with the other three initial Schools on which Griffith was founded, the School of Australian Environmental Studies had a considerable degree of autonomy with respect to budget distribution, appointment and promotion of staff, research relationships and curriculum development. Sometimes referred to as a "lifeboat model" (Braddock et al. 1994), this form of organisation was consistent with the University's desire at the time to promote the study of issues of concern to society, which are necessarily interdisciplinary in nature.

Whilst this School system was conducive to interdisciplinary activity, interdisciplinary teaching and research was not at all common when the University was founded (Ledford 2015), and this may have contributed to a degree of initial suspicion of the School and University in some public and institutional

quarters. In recent years principles conducive to interdisciplinary research are beginning to emerge more clearly (Brown et al. 2015).

Especially during the early growth of the School, developing quite new and innovative teaching programmes was obviously a priority. Whether or not such teaching contributions were adequately recognised in a promotions policy which also included research and community/university service was a cause of some contention.

BACHELOR OF ENVIRONMENTAL STUDIES DEGREE

In the founding years of the School there was awareness of necessary interactions of environmental studies with many sciences, the focus being on the following:

- The physical and chemical sciences
- The biological and ecological sciences
- The land use sciences and their interactions with soil science, soil and water conservation, agriculture, and ecosystems
- The social sciences including anthropology, economics and sociology, focussing on society/environment relationships.
- The interaction of all the above with human health, and
- Last but not least, the applicable mathematical sciences with their vital contributions to mathematical modelling and statistics

The first year of the undergraduate program, which was called the Foundation Year, had two broad objectives.

Perhaps the major objective was to engage students in an exciting, expansive but coherent understanding of the world and its societies from an environmental perspective. Starting with plate tectonics, how can we reach some understanding of the changing earth surface, its development of soil and vegetation and the life forms it sustains under the great variety of climatic regimes. What characterises the web of relationships or ecology of the vast variety of life forms, and how have humans used, selected and modified them? Also how have humans utilised and transformed the earth's offerings into resources, then how have these complex processes been influenced by social organisation and human culture? Gaining some understanding of Aboriginal culture led a student to say "This is the first time I realised I too had a culture!" How then are resources developed and shared, and what are the achievements and limitations of economic and social systems in such distributional aspects of human life?

Importantly, the development of such concepts and understandings ensured that all students experienced something of the variety of 'areas of concentration' available to them in later years, so enabling them to make informed choices in focussing on those areas they found they enjoyed and wished to pursue.

The second objective of the Foundation Year was to provide knowledge and skill sets basic to later course development, and to employment. A Self-Pacing in Mathematics or SPIM course achieved what the available advice said was quite impossible - namely to take students in one year from any entry level of competence in mathematics to a mastery of basic calculus. Most importantly, mathematical and statistical modelling was applied to understanding environmental systems. Such skills led to highly sought-after students. With teaching commencing at Griffith in 1975, an introduction to computers and computing was obviously also essential.

Another skill-based activity was a practical laboratory program including a Self-Pacing in Chemistry course - both activities being successful only because they were self-pacing in nature.

A most original orientation program, involving first year students and staff, was instituted at the commencement of teaching in 1975, and continued until 1987, when larger student numbers made this off-campus exercise impractical. Staff and students were housed communally at Tallebudgera Fitness Camp on the Gold Coast, participating in seven different local environmental investigations over several days. This proved to be a great learning experience and bonding activity.

This thumbnail sketch may help in catching the flavour of the dimensions of Foundation Year.

The areas of concentration in the second and third years of the three-year bachelor degree program recognised that successful employment of graduates required some recognisable focus of development in knowledge and skills. These areas of concentration are now briefly described.

PHYSICS/SOILS/MATHS AREAS OF CONCENTRATION

Environmental issues are essentially diverse, but commonly include consideration of this earth with its soil, its resources, its water and its atmosphere. Such issues range from local stream pollution to questions of global warming involving enrichment of the earth's atmosphere by carbon dioxide and other greenhouse gases.

The "areas of concentration" offered in the second and third years of the Bachelor of Environmental Studies program included Environmental Physics, courses in the Soil and Water Sciences involved in sustainable land management and pollution reduction, together with Mathematical and Statistical modelling. Close integration between all these courses and the application of mathematical methods was an important and strengthening feature. Field activities and laboratory programs were an important component developing experimental and data analysis skills. These courses were designed to share the basic physical knowledge required to understand the processes involved in the sustainable use and management of the earth's land and water systems, and the essential environmental services which they provide. Mathematical modelling was an essential component in interpreting the processes in such systems, but modelling is also recognised as playing a role quite generally throughout all sciences.

Environmental Physics describes the area of knowledge which supports an understanding of all physical processes such as soil erosion, the movement of water and pollutants over and within soil and water bodies. In turn, knowledge of processes provides the basis for designing or evaluating alternative management practices which are more compatible with sustainable land use and healthy and productive waterways and oceans. Physical process knowledge is also involved in understanding earth-atmosphere interactions such as evaporation, photosynthesis and heat exchange.

A strong role in the teaching of mathematics was in supporting systems modelling of all kinds, including analytical and statistical methods. Such methods greatly aid in understanding processes and predicting the consequences of human activities.

ENVIRONMENTAL CHEMISTRY AND HEALTH AREAS OF CONCENTRATION

When teaching began in 1975, environmental chemistry was a nascent area of science. Although the first-year self-pacing program in chemistry mentioned earlier met the need to recognise chemistry as a fundamental component of any science-related program, later-course teaching in environmental chemistry was dependent on developments in research in that area. This development initially built on analytical chemical studies of pesticide residues, and study of the pathways and implications of such pesticide residues was greatly assisted by new modelling developments in predicting the fate of chemicals moving between different environmental components.

Such advances helped develop research in the School on the bioaccumulation of pesticides, and their adverse effects on aquatic organisms and the natural environment. This research soon led on to study the human health effects of chemical exposure, and the development of risk assessment methods to set exposure guidelines, both for the human and natural environment.

The research outlined above played a major role in supporting the development of post-first year courses in this concentration area. Broader community and public health issues also received attention in research and teaching, linking environmental chemistry with the implicit social and public policy issues involved in responding to its findings.

BIOLOGICAL AND ECOLOGICAL SCIENCES AREA OF CONCENTRATION

Students interested in the ecological sciences and the principles underlying natural and human-affected ecosystems were required to take a basic course in 'Environmental Biology' to bring them up to a common skills level, following the model of the SPIC and SPIM courses undertaken in the Foundation Year. The biology course provided field collection and laboratory experience of plant, invertebrate and vertebrate diversity, and the basic biological and physiological knowledge to support the ecological courses of subsequent years. Courses in Natural, Agricultural and Aquatic Ecosystems followed and could be combined with selections from the Physics/Soils/Maths and Chemistry areas. Students were also offered the option of doing a Special Topic, a study program tailored to the special interests of the individual, and ranging across many fields. Naturally

Special Topics were very popular with the students and generated some rewarding outcomes. Fieldwork was a strong component in the early years of the ecology area of concentration, with trips to North Stradbroke Island, Binna Burra (Lamington National Park) and rural locations to experience conservation and management problems first hand.

SOCIAL SCIENCES AREA OF CONCENRATION

Society and nature relationships were established as a major area of study in the environment school, and a Foundation Chair in the Social Sciences was established. After that, other staff were appointed across the disciplines of anthropology, economics, policy or political science, social geography and sociology. It was a diverse group but one that was generally coordinated around issues of land and water conservation, social and environmental impacts of development, environment and health, Indigenous culture and traditional rights to land. These interests continue with increasing emphasis on issues of environmental sustainability, climate change and energy, animal and human interaction in urban, regional and recreational areas, community and national responses to large-scale natural disasters such as tsunamis. Research sites concentrated on Australia, but research has taken an important international focus so that Australian environmental issues can be considered in a comparative perspective. Projects included analyses of community relations in the cement industry comparing Switzerland and Queensland sites, the changing structure of agricultural production and what that means for rural communities and land conservation, environmental and population health in China and Vietnam, human responses to Dingo habitats in Australia, and the lessons for Australia from Japanese responses to tsunami disasters. Significantly, these interests bring social science researchers into direct and continuing relationships with biophysical scholars and researchers furthering the understanding and contribution of both groups.

RESEARCH AND POSTGRADUATE TRAINING

A challenge to early appointments in this new environmental school was to select staff whose interests and achievements helped cover the wide curriculum range adopted. Development of research programs and linked postgraduate training began almost immediately across the concentration areas, and through interdisciplinary projects. Interestingly, PhD candidates were the first students taken into the School, and one of the first to graduate became the VC of Queensland University of Technology.

An early research project was focussed on the contemporary issue of excessive soil erosion on agricultural lands in the Darling Downs of South East Queensland. Referring to the typical black soils of the region the newspaper headlines read: "The Downs Bled Black Blood". The project included a study of the socio-economic factors affecting adoption of soil conserving practices (Earle et al. 1979), and evaluation of the spatial patterns of net erosion and deposition using soil coring and Cs-147 tracer techniques (McCallan et al. 1980), illustrating the inter-disciplinary nature of research in the School. This is one of the School's areas where there was strong interaction and collaboration between soil scientists, terrestrial ecologists and environmental sociologists. A research and teaching program on farmer responses to soil erosion, adoption of conservation methods and studies in the structure of agriculture production was developed (Rickson et al. 1987).

Understanding soil erosion and deposition process, and application of this knowledge using mathematical models at a range of spatial scales has been an important research contribution from the School. In the training of a significant number of local and overseas PhD students, the Griffith University Tilting flume Simulated Rainfall facility (or GUTSR) has been vital, resulting in many publications such as the internationally-used soil erosion model of Hairsine and Rose (1991, 1992).

Contamination of the human and natural environments with toxic chemicals has been a prime area of public concern as well as a topic for environmental research in the School. Post graduate projects covered the occurrence of pesticides and petroleum hydrocarbons in aquatic areas particularly the Great Barrier Reef (Miller and Connell 1980)). Later projects involved the use of fugacity modelling to explain the occurrence of chlorohydrocarbon pesticides in the environment, particularly fish, in off-shore Sydney (Mortimer and Connell 1995). This led on to projects on prediction of the environmental properties of chemicals such as toxicity and half-life using Quantitative Structure Activity Relationships (QSARs). Later the need to interpret the biological effects of the chemicals in the environment became a focus of postgraduate student research (Hau et al. 2000).

A challenging environmental inquiry of the mid-1970s involved threats from sand mining to the unique features and biodiversity of Fraser Island, the world's largest sand island. Dr Peter Stevens stepped aside from teaching in AES to serve on the Fraser Island Inquiry (1976), which stopped the sale of mineral sands, and thus sand mining, so contributing to protection of the island as a UNESCO World Heritage site in 1992. Research on the geomorphology, biodiversity and sensitivity of freshwater dune lakes provided vital evidence to the inquiry and the World Heritage nomination (Arthington 1977; Arthington and Watson 1982). Discovery of new freshwater species endemic to sand dune lakes and wetlands supported this nomination and the declaration of Moreton Island as a National Park. More recently, a Griffith PhD candidate studied the impacts of recreation and tourism on Fraser Island's dune lakes and went on to become an expert on the implications of tourism and climate change for coastal ecosystems (Hadwen and Arthington 2003, 2011).

CONCLUSIONS

This brief account describes the interdisciplinary environmental studies program implemented in the foundation years of Griffith University, but let us remember that universities have a long and proper history of devotion to disciplinary education and research. Thus, as an essentially interdisciplinary area of study and activity, environmental studies can be a somewhat contested area, subject to possible suspicion and misunderstanding. There are pressures on it to conform to a disciplinary framework, such as ecology, geomorphology or policy and economics, such conformity assisting its ready acceptance as a recognisable science, and so assuring its "respectability" in the general University world.

The philosophical foundations of Griffith's interdisciplinary teaching, research and post-graduate training in the environmental sciences have stood the test of time as reviewed by Metcalf et al.(1996), with graduates from the Bachelors program being employed nationally and internationally in many spheres. The research programs of those early years have mutated and blossomed into respected research consortia and institutes that continue to address and inform contemporary challenges, such as sustainable land management, cities and regional areas, environmental health, chemical impact risk analysis, biodiversity conservation, the management of rivers and wetlands, urban planning, and environmental futures.

LITERATURE CITED

ARTHINGTON, A.H. 1977. Ecology of Fraser Island Lakes. *Occ. Papers in Anthropology*. Anthropology Mus. University of Queensland 8: 135-138.

ARTHINGTON, A.H., & WATSON, J.A.L. 1982. Dragonflies (Odonata) of coastal sand dune fresh waters of south-eastern Queensland and north-eastern New South Wales. *Aust. J. Mar. Freshwat. Res.* 33: 77-88.

BRADDOCK, R., J. FIEN & RICKSON, R.E. 1994. "Environmental Studies: Managing the Disciplinary Divide". *The Environmentalist* 14: 36-46.

BROWN, R.R, DELETEC. A, & WONG, T.H.F. 2015. How to catalyse collaboration. *Nature.* vol. 525: 315-317.

CONNELL, D.W. 1971. The Great Barrier Reef Conservation Issue, *Biological Conservation*, **3**:249254 (Published also in Search, **2**:188192, also "Oceanography: Contemporary Readings in Ocean Science", Oxford University Press of New York, 1973).

EARLE, T.R., ROSE, C.W., & BROWNLEA, A.A. 1979. Socioeconomic predictors of intention toward soil conservation and their implication in environmental management. *J. Env. Managt.* 9: 225236.

EDITORS OF NATURE. 2015. Mind meld: interdisciplinary science must break down barriers between fields to build common ground. *Nature.* vol. 525: 289+

HADWEN, W.L., & ARTHINGTON, A.H. 2003. The significance and management implications of perched dune lakes as swimming and recreation sites on Fraser Island, Australia. *The Journal of Tourism Studies* 14 (2): 35-44.

HADWEN, W.L., & ARTHINGTON, A.H. 2011. Visitor impacts and climatic variability will shape the future ecology of Fraser Island's perched dune lakes. *Proc. Royal Society of Queensland* 117: 485-493.

HAU, K.M., CONNELL, D.W., & RICHARDSON, B.J. 2000 . Use of partition coefficients in setting health guidelines for volatile organic compounds. *Regulatory Toxicology and Pharmacology* 31, 22 – 29.

HAIRSINE, P.B., & ROSE, C.W. 1991. Rainfall detachment and deposition: Sediment transport in the absence of flow-driven processes. *Soil Sci. Soc. Amer. J.* 55: 320-324.

HAIRSINE, P.B., and ROSE, C.W. 1992. Modelling water erosion due to overland flow

using physical principles: II. Rill flow. *Water Resources Res.* 28: 245-250.

LANE, M., ROSS, H., DALE, A., RICKSON, R.E. 2003. Sacred Land, Mineral Wealth, and Biodiversity at Coronation Hill, Northern Australia: Integrating Knowledge Systems in SIA. *Impact Assessment and Project Evaluation.* 21:89-99.

LEDFORD, H. 2015. Team science. *Nature.* vol. 525:313-315.

METCALF, W., BRADDOCK, R., URQUHART, J., & NEUMANN, R. 1996. "Evolution of Environmental Sciences. The first 25 years". A Griffith University production. Brisbane.

MCCALLAN, M.E., O'LEARY, B.M., & ROSE, C.W. 1980. Redistribution of caesium137 by erosion and deposition on an Australian soil. *Aust. J. Soil Res.* 18: 118128.

MILLER, G.J., & CONNELL, D.W. 1980. Occurrence of petroleum hydrocarbons in Australian seabirds, *Australian Wildlife Research*, **7**:281293.

MORTMER, M.R. & CONNELL, D.W. 1995. A model of the environmental fate of chlorohydrocarbon contaminants associated with Sydney sewage discharges. *Chemosphere*, 30:2021-2031.

QUIRKE, N. 1996. Preparing for the future: a history of Griffith University 1971-1996. Boolarong Press, Brisbane.

RICKSON., R.E., SAFFIGNA, P., VANCLAY, F. MCTAINSH, G. 1987. Social Bases of Farmers' Responses to land Degradation,' Pp. 125-139 in A. Chisholm and R. Dumsday (eds) *Land Degradation: Problems and Prospects*. Sydney: Cambridge University Press.

SNOW, C.P. 1959. The Two Cultures. Cambridge University Press, London.

TOPLEY, J. & WILLETT, F.J. 1975. "The Organization of a New University". *Journal of Educational Administration.* 14: (Iss. 1) 54-69.

UNESCO. 1990. "Environmental Education at a General Level in Tertiary Institutions of the Pacific Subregion." Proceedings of a Seminar and Workshops. Graduate School of the Environment, Macquarie University, Sydney.

Address of Authors: Griffith School of Environment, Griffith University, Nathan Campus, Brisbane, QLD 4011, Australia.

AUTHOR PROFILES

Calvin Rose is an Emeritus Professor with the Griffith School of Environment, where he was inaugural Dean in 1973-1978. Having been invested as a Life Member of the Royal Society of Queensland in 2016, Calvin continues research with colleagues in the School's Australian Rivers Institute. In this he draws upon long experience in soil science and environmental physics in modelling land and water degradation processes.

Angela Arthington is an Emeritus Professor in the Australian Rivers Institute, Griffith University, where she established the first freshwater research centre in 1997. Angela continues research on the ecology and management of rivers with emphasis on maintaining environmental flows for fish and protecting river integrity generally. She serves on the Council of the Royal Society, on several journal editorial boards and supports the research of many colleagues at Griffith and internationally.

Des Connell is an Emeritus Professor with the Griffith School of Environment where he was Dean of the School following Calvin Rose as Inaugural Dean. He was made a Member of the Order of Australia and awarded a Doctor of Science degree for his research on the behaviour and effects of chemicals in the environment. His research is currently directed towards the assessment of the health and ecotoxicological risk of chemicals in the natural and the occupational environment using probabilistic techniques.

Emeritus Professor Roy E. Rickson is a member of the Griffith School of Environment and the Environmental Futures Research Institute at Griffith University. His research is in the areas of environmental sociology and the sociology of agriculture focusing on changes in the structure of agricultural production, land degradation processes and farmer responses as well as tensions between natural resource development on rural lands and farming communities. Current writing is on industry and rural community relationships in mining developments comparing Switzerland and Australia.

THE EMERGENCE OF FREDERICK STRANGE, NATURALIST

COMBEN, P.

"The Wall of the Dead," a web based "Memorial to Fallen Naturalists" contains more than 500 names of collectors, naturalists and scientists who died or were killed while actively seeking information or answers for science (Conniff 2017). But as if history continued to slight natural history collector Frederick Strange, killed by aboriginals in 1854 whilst collecting natural history specimens on Middle Percy Island on Queensland's central coast, the memorial long omitted him. Leaders of the first two expeditions that Strange took part in list at the commencement of their reports the party members, omitting Strange. Only when Strange becomes involved in the action does he receive fleeting mentions. Our knowledge of Strange and his collecting in Australia and New Zealand has improved in recent times, but there are still conflicts as to his birth, upbringing, early career, literary competency, financial management and contribution to science. Perhaps the greatest calumny committed is that the ultimate fate of those accused of his murder and then discharged has been surrounded in mystery. One source has the accused being returned to Moreton Bay "where they were hanged." A second suggests the entire aboriginal party pinned to death in Darlinghurst Gaol. A third assertion has the discharged prisoners jumping their ship at Gladstone and being murdered by local aboriginals. This paper seeks to provide a fuller biography than previously available, a re-assessment of Frederick Strange, Naturalist, and a detailed examination of the treatment and possible fate of those accused of his murder.

INTRODUCTION

England in the throes of the industrial revolution during the first half of the 19th century provided few opportunities for an orphan with perhaps limited prospects (Lines 1991). In the likely year of Frederick Strange's birth and not far from his apparent birthplace the Ely and Littleport riots occurred between May 22 and 24, 1816. Soldiers and sailors returning from the battle of Waterloo found a country different to the one they had left and no prospect of work. It should not be surprising that Strange, at age 14, left Norfolk (Anon. 1855c) seeking adventure, if not fortune, elsewhere. Eventually arriving in South Australia Strange's short life would be full, adventurous and benefitting his adopted land as a collector of valuable natural history specimens and information. Strange is one of the Victorian collectors who "sacrificed his life in the pursuit of natural history on the east coast of Australia" (Gould 1863). In spite of this sacrifice little is known about his early life, published details of his life are often patchy or incorrect and no place has been awarded him within the pantheon of Australian collectors. Assessments of him have varied from "Strange was semiliterate" (Lemmer 2009) to Strange was a collector of "much of scientific importance," (Fisher 2004). The circumstances of his death are known (Chimmo 1855), but the published accounts on the fate of those accused, apprehended and discharged are inconsistent (CHAH 2017 & Variorum 1898).

Fifty years after Strange's death the British Museum's Curator of Birds could not provide any information about him beyond "he made beautiful skins" and John Gould "always spoke of him with high appreciation

as a collector" (Bowdler Sharpe 1906). In his adopted land he fared slightly better with a thumb nail sketch being published in 1908 (Maiden 1908). A fuller biography was produced in 1947 by Major Hubert Whittell a retired army officer (Whittell 1947). Whittell wrote extensively on the natural history of Western Australia and his painstaking research is the basis for much of our knowledge of Strange. An Oxford Dictionary of National Biography entry in 2004 (Fisher 2004) also provided new information. Recently he has been the subject of examination of the social perceptions of remunerated collectors as against naturalists and comparisons with other 19th century collectors (Coote 2014 & Noonan 2016).

Strange made substantive contributions to Australian natural history yet his personal sacrifice and the story of his accused murderers have not attracted the same attention as that given contemporary collectors John Gilbert and John MacGillivray. Strange has remained cocooned for too long.

ORIGINS

When Frederick Strange returned to England in 1852 with a collection of natural history specimens, publicity of his arrival (Anon 1852c) referred to his Aylsham, Norfolk origins but provided no details. Biographical coverage gives a birth year of 1826 (Maiden 1908), but this is disputed (Whittell 1947) on the basis of logic. Strange died at age 38 in 1854 so 1816 is the likely year of his birth.

A newspaper notice "Appeal for the Widow and Orphans of the Late Frederick Strange" who were, "... left in a state of great destitution," placed in the Norfolk Chronicle & Norwich Gazette on December 15, 1855 (Anon 1855d) more than a year after his death, provides some information on his early life. The appeal states, "Frederick Strange was a native of Norfolk, where at an early age he was left an orphan, ... and (was) sent to sea at age fourteen."

Six years after Strange's death a Sydney death notice was published for William John Jackson Weaver, the "brother to the late Mr Frederick Strange" of Sydney (Anon 1860). In a number of letters from Frederick Strange to John Gould reference is made to his brother collecting for him in Australia. (Sauer 2001:148). Anne Coote believes Weaver's death notice makes it likely that Strange was "the son (natural or adopted) of Mary Weaver, nee Alcock, sister of Trivet Alcock, a Norfolk schoolmaster whom Strange called uncle," (Coote 2014). Whilst the appeal's "orphaned" reference makes it unlikely he was the natural son of Weaver, no legally recognised adoption system was in place until 1926 but an informal system of care may have been in place. A reference in a letter from Strange to Gould concerning the death of, "my aunt Peacock, who owned The City of London Arms," has him related to a wealthy family of London publicans (Sauer 2001:220 & Coote 2014).

All that is known of Strange from 1830 to 1836 is that he spent time at sea. The newspaper appeal stated that he "served at sea with much credit." By the time of his marriage in 1841 he was described as "Chief Officer of the General Steam Navigational Company's ship, Maitland" (Anon 1841).

SOUTH AUSTRALIA

The publicity of his 1852 arrival in England refers to him embarking "in the third vessel which left the shoes of England" for South Australia after its establishment (Anon., 1852c). This was the Cygnet, which arrived on June 6, 1836. However no record exists of him being a passenger on that ship nor any ship around that time. The belief of Whittell that as an experienced sailor he could have come as a crew member seems plausible. Interestingly the original crew members other than the Captain and "one of the original crew," all left the ship at Rio de Janeiro, after argument with the captain" (History SA 2011). Thus Strange, if part of the crew, must have been the sole crew member who did not leave the ship at Rio.

His early employment in South Australia included fishing and assisting with surveys. We know Strange was in South Australia in early 1838. On July 14, 1838 the Governor of South Australia Captain John Hindmarsh RN wrote a reference for Strange certifying his knowledge of Strange over six months "during which period his sobriety, honesty, and good conduct have been uniformly good and steady" (Whittell 1947).

Strange accompanied Captain Charles Sturt on an expedition from September 26 to 30, 1838 to the Gawler River (Whittell 1947). Early in 1839 Strange revisited the area with George Stephens (Stephens 1839). Later reports would provide the names of three members of the party "in search of rich country" but no initial mention of Strange. Impressed with the land Stephens obtained pre-emptive rights over the land through an immediate application for a Special Survey.

Controversy ensued connected with the way in which Stephens marketed the land. Whittell describes Strange as being "involved" in the transactions of "a somewhat notorious and unsavoury" matter. Whittell had available to him certain family archives, now lost, which included a letter showing a potential benefit to Strange (Whittell 1947). This may be overreach as there is no indication that Strange was "involved" in any transaction.

In late May or early June 1839 he met visiting British naturalist John Gould and accompanied him on field trips (Whittell 1947). In September 1839 Gould was writing to Strange from Sydney. Strange's reply of September 13, 1839 refers to collecting "Cranes" for Gould and his intention to move to New South Wales in late 1839 or early 1840 (Sauer 1998:101). On November 13, 1839 he wrote again to Gould advising that he had despatched "between Fifty and Sixty lots of Eggs and 5 Birds" (sic) (Sauer 1998:125).

On November 22, 1839 (Sturt 1840) the South Australian Governor, Colonel George Gawler, left Adelaide to inspect land along the Murray River and the navigation possibilities of the Murray. The exploring party was named in later official reports but no mention was made of the presence of support staff including Strange. On December 11 a number of the members of the party were left at a Murray River base camp whilst the Governor and others left for a three day exploration to the northwest.

With the loss of most of the contents of a water barrel, half the travelling party's water supply, and finding no surface water the situation for the explorers became dire. A horse was "bled" to obtain liquid which was drunk (a quart in the case of the Chief of Police) and this provided some relief as they retreated. On the return leg Henry Bryan, a young man and son of a friend of the Governor, offered to return more slowly leading the Governor's exhausted horse. Bryan was never seen again. Only when details of the ensuing search were published is the presence of Frederick Strange revealed as he walked, searching with others, "along the main road."

Gould later made Strange again the invisible man of the expedition. Gould wrote in his "Handbook of Australian Birds" (Gould 1865:322) that a splendid fairy-wren was collected by "one of the party that accompanied His Excellency Colonel Gawler and Captain Sturt when they visited the Murray in 1839". The nameless person was Strange.

MARRIAGE

By 1841 Strange was living in New South Wales. On January 28th, 1841 the Sydney Morning Herald carried a "Married" notice stating "Yesterday at St Phillip's Church, by the Rev. Cowper, Frederick Strange, Chief Officer of the General Steam Navigation Company's Ship Maitland, to Miss Rosa Prince, third daughter of Mr George Prince Canterbury, Kent England," (Anon 1841). Rosa was born in Canterbury the daughter of George Prince and Elizabeth Sophia Prince.

George William Strange was born to the couple on November 23, 1841 at Gosford (Whittell 1947). A year later a burial certificate shows the infant to have died on October 20, 1842, at East Gosford and his father, Frederick Strange, being the "mate on the Tamar steamer". However with a second child, Thomas Frederick, being born in Sydney and baptised on May 27, 1843 it appears that Strange had moved to Sydney.

In 1845 the Stranges were operating a boarding house which Loch believed was known as the Naturalist's Home at 8 Bridge Street, near the Rocks, Sydney (Loch 1989-1990). No primary source has been found to support this view. Naturalists and collectors John Gilbert and John MacGillivray stayed on occasions (McAllan 1994 & Noonan 2016).

On February 29, 1848, "all the household effects of Mr Strange" at Bridge Street were auctioned. (Anon. 1848a). The auction included, "Large cabinet, containing birds, insects, shells, etc, etc" and "Gould's Monograph of the Family of Kangaroos." No reason is apparent for the auction. A letter from Strange printed in the Annals of Natural History dated the day after the auction has the address Fore Street, Sydney. A calling card with the name Mr Frederick Strange of Norfolk Cottage, North Shore is attached to the New South Wales Archives records of his murder.

The Strange family moved to Moreton Bay in March 1850, (Anon 1850). Strange had apparently previously collected at Moreton Bay between September and December 1844 (Sauer 1999:343) and again in 1847 when he indicated he was to visit the Bungu Bungu country (Bunya Mountains) north of the Darling Downs. Gould believed that he intended to collect live

finches and other birds on the Darling Downs (Sauer 2001:504). Strange collected extensively around the Moreton Bay islands. In July 1851 Dundalli, an aboriginal guerrilla leader in southern Queensland saw Strange collecting around Bribie Island and challenged him to a fight. Libby Connors believes "Dundalli's challenge to hand-to-hand combat was a method of dispute resolution according to traditional law and common in southeast Queensland" (Connors 2006). Strange published in the Moreton Bay Courier about the intricate and extensive work involved in Aboriginal shelter construction on Bribie Island.

The family returned to Sydney in February 1852 (Anon 1852a) prior to sailing to England. Leaving Sydney on March 10, 1852 (Anon 1852b) the Stranges and three children were away until March 21, 1853. Other than that he headed to Norfolk on his arrival, little is known of his travels in England and the continent. Strange was in Paris on July 20, 1852 where some of his clients were resident including the conchologist Gerard Paul Deshayes. The family's return to Australia was aboard the Resolute. On January 23, 1853, Rosa gave birth off the Cape of Good Hope to a baby boy, whom his parents named Frederick Resolute Strange.

COLLECTOR AND NATURALIST

The difference between a self-employed collector and employed or wealthy amateur naturalists was real in Victorian Britain, (Coote 2014 & Noonan 2016). MacGillivray employed by the British Lords of the Admiralty as a naturalist on HMS Rattlesnake could be in awe of the knowledge and dissecting skills of the young surgeon naturalist Thomas Henry Huxley and lament "my duties too often merge into those of a mere collector and preserver of specimens," (Goodman 2005). Strange commenced as a generalist collector, needing to turn a profit from anything that would sell.

Later in life, with some notable clients and acquisitions Strange sought to present himself as a naturalist by publishing occasionally in both the Moreton Bay Courier and Sydney Morning Herald notes on birds, shells, New Zealand travels and aboriginals. The author was generally described as "Frederick Strange, Naturalist". Coote believes that in Victoria's era the recognised naturalist required a "gentlemanly demeanour," "appropriate imperial connections" and "proven disciplinary knowledge" (Coote 2014:99) Strange lacked the background and connections to be viewed as genteel or being well connected. But in today's world, where core competencies provide the basis for professional competency, Strange with his field skills and literary efforts would be deemed a naturalist.

An "assiduous collector of shells" (Hedley 1905a) it is within conchology that Strange has left his most distinctive mark. He sought beach specimens and dredged widely for shells in the vicinity of Sydney and Moreton Bay. Strange's New Zealand collection, gathered while travelling with HMS Acheron as it mapped parts of the New Zealand coast in 1849, was significant. He was "the first, and for half a century the last, to dredge off the New Zealand coast, and (he) discovered many species enumerated in this report" (Hedley 1905b).

Travelling to England in 1852 he sold his collection of shells to "that Napoleon of conchology Hugh Cuming", (Shirley 1917). That collection provided material for many papers by Arthur Adams and Gerard Paul Deshayes. In 1866 the Natural History Museum of London purchased the 82,992 specimens in the Cuming collection, including Strange's material, for six thousand pounds.

Prior to his last trip, Strange donated "some rare shells" to the Australian Museum (Loch 1989-90). After Strange's death, among the donations made to the fledgling Australian Museum, by his widow, was the last item Strange collected, a "lovely *Cardium bechei* from Percy Island" (Hedley 1905a). Regarded at the time as unique it became the subject of a bidding tussle between the colonial Governor and a Trustee of the Australian Museum (Loch 1989-90).

Gould in his Handbook of Australian Mammals (Gould 1863) states the yellow-footed rock-wallaby, "was one of the last discoveries made by one who sacrificed his life in the pursuit of natural history on the east coast of Australia and it would have been well if the name of Frederick Strange had been associated with the species." Collected by Strange in the Flinders Range, the two specimens were bought and described by Dr J E Gray of the British Museum, (Gray 1854).

Whittell believed Strange was probably the first European to have made field notes on the, now extinct, toolach wallaby (Whittell 1919). Although Waterhouse described the wallaby, Gould published important behavioural information from Strange. During his Clarence River collecting he acquired a number of

rats and mice perhaps including the type specimens of the Hastings River mouse and canefield rat. Both have historically been credited to the collecting of John Gilbert just prior to the commencement of his fatal last mission, this is now doubted with credit being given to Strange (McAllan 1994).

Also while collecting on the Clarence River, Strange obtained the type specimens of the sooty owl, plumed frogmouth and the eastern form of the little shrike thrush, (McAllan 1994). Gould described a new species of yellow robin collected by Strange, but this has now been combined with previously described species. Strange brought what are likely to have been the first living kiwis to Australia following the HMS Acheron voyage (Anon 1849).

The type specimen of Albert's lyrebird was collected by Strange. Writing in the Handbook of Australian Birds Gould (Gould 1865) states surprise at the discovery of such a remarkable bird within New South Wales considering how long the colony had been searched by collectors. Gould includes field notes from Strange on the ten days spent in the Turanga Creek area of the Richmond River.

Substantial numbers of insects were sent by Strange to Gould for sale. On August 4, 1847 he informed Gould (Sauer 2001:165) that among the material forwarded were "16 Hundred Insects or more" (sic). On January 31, 1848 he received from Gould five pounds "for insects," (Sauer 2001). In February 1850 Gould informed Strange, "The two butterflies which arrived are very beautiful specimens and I got four pounds for them" (Sauer 2001:395). Also in 1850 Strange sent eight Lepidoptera to England and these may have been the first from Brisbane. The collection of natural history specimens he sold when he returned to England in 1852 included a further 22 Lepidoptera (Edwards 2008).

In 1855 a collection of "about 45 species of plants collected by Mr F. Strange, in the neighbourhood of the Richmond River, N.S. Wales," were donated by Mr H Sawerby to the Linnean Society (Anon 1855a). After his death, plants he obtained were featured in advertisements for a plant sale in Hooker's 1857 Journal of Botany (Hooker 1857).

Included in the London Morning Advertiser announcement of his arrival in England (Anon 1852c), is the information that he had "brought with him the only living specimen in Europe of the Gigantic Water Lily (*Nymphoea gigantea*)".

The range of Strange's collecting activities is revealed in his correspondence with Gould (Sauer 2001): "70 fossils" (August 28, 1847), "72 Crustacea" (October 1847), "eight species of lizard" (November 1847), "two boxes of Crustacea" (July 28, 1848), and "49 specimens of fish" (August 7, 1848). A 13cm hei tiki carved from greenstone collected by Strange during a stopover of the HMS Acheron in Auckland in 1849 was sold in Paris in 2010 (Coote 2014). In August 1854 Strange presented to the Australian Museum a "portion of skin of an aboriginal preserved by the natives of Bribie Island" (Anon 1854a Coote 2014).

NOMENCLATURE

Botanical names commemorating Strange include *Strangea*, a genus within the Proteaceae, containing three species. The originally named Grevillea *strangea* has now been grouped in the *Strangea* genus as *Strangea linearis*. The originally named *Eutaxia strangeana* (Turcz) has become *Dillwynia retorta*.

In the animal kingdom commemorations include the genus *Strangesta* (carnivorous snails) containing four species. *Echotrida substrangeoides* is the Glastonbury carnivorous snail, and *E. strangeoides* is the spiral-lined carnivorous snail. Twenty two molluscs have *strangei* as a specific name, their common names include Strange's trigonia and the Border Ranges staircase-snail.

FINAL VOYAGE

In mid-September 1854 Strange prepared to head north on his newly purchased ketch Vision for the purpose of searching "for specimens of natural history" (Anon. 1854e). The Vision commenced its fateful voyage from Moreton Bay on September 29, 1854 with 10 people aboard. There are no indications of any naivety or shortcomings in the preparations for the trip. Strange, as a seaman knew the sea and had experienced aboriginal interaction throughout his time in Australia.

The ketch travelled northward and called at a small island off Cape Capricorn before arriving at Second Percy Isle (now Middle Percy) on October 14, 1854 (Anon 1854d). In the evening Strange and three others went ashore for an hour without seeing any of the aboriginal people believed to be on the island. At 8.30am the next day Strange went ashore with Walter

Hill (botanist), Richard Spinks (assistant to Strange), Deliapy an aboriginal interpreter and collector from Moreton Island, William Spurling (mate) and Henry Gittings (cook and steward). They quickly had contact with aboriginal people who seemed friendly. Walter Hill decided to walk by himself to the top of the island and left the group. Strange and party remained on the beach to collect shells (Hedley 1905).

When Hill returned he saw the body of William Spurling in a patch of mangroves his neck wounds consistent with murder. Deliapy, who was hiding among the beach rocks, made contact with Hill and indicated the other party members were dead. He had escaped by running from the beach. Deliapy described how one aboriginal had without apparent warning speared Strange in the leg. Strange pulled the spear out and shot his assailant. The entire party was then killed. Anne Coote is of the view that the murders were possibly undertaken by the indigenous owners "in a judicial spearing gone wrong (Coote 2014)."

Hill and Deliapy waited until sundown to return to the Vision in the ship's boat. Musket shots were used unsuccessfully over the next three days to try to attract the attention of anyone left alive. The Vision returned to Moreton Bay. An immediate inquiry was held by the Government Resident Captain Wickham and news of the deaths sent to Sydney. The Sydney Morning Herald reported that Strange had "fallen a sacrifice to his great confidence in the peaceable disposition of the (aboriginals)" (Anon. 1854d).

THE AFTERMATH

Eventually the colonial authorities in Sydney sent a ship to the site of the murders to establish what had occurred and if possible to arrest the offenders. HM Steamer Torch under the command of Lieutenant Chimmo RN, arrived at Second Percy Isle on January 29, 1855. Several days were spent befriending the aboriginals and obtaining information on the occurrences of the previous October.

The skeletal remains of Spurling were found in an area of mangroves, the ship's doctor confirming death by trauma to the head. Lieutenant Chimmo's eventual report (Chimmo 1855) states "from the women I had sufficient information to condemn every" male on the island. He determined that Frederick Strange and his colleagues had been murdered, and their bodies, other than Spurling's, dumped at sea. Chimmo took three male aboriginals prisoners. The prisoners, accompanied by their families comprising three women and four children, were confined on the Torch and eventually taken to Sydney.

Contrary to some accounts (Variorum 1898 & McDonald 1988) it was the remains of Spurling that were taken to Port Curtis. He was buried near the Government Residence, next to the fresh grave of the secretary to the Government Representative, with what pomp and ceremony the Government Resident and a troop of mounted Native Police could muster. The burial site is within the state heritage listed Friend Park and Graveyard, Barney Point, Gladstone (Variorum 1898).

The three arrested men in the company of their families arrived in Sydney on March 18, 1855. They appeared before the Water Police Court magistrates and were remanded to Darlinghurst Gaol for seven days (Anon 1855b). There followed three hearings without interpreters. At the third hearing, April 10, 1855, the accused were discharged (Anon 1855c). That the Percy Islanders could be discharged for lack of an interpreter had solid legal precedent. In 1837 Chief Justice Dowling released Wombarty a Port Macquarie aboriginal charged with murder, as there was no European in the colony who could translate his dialect. (Anon 1837).

The magistrates ordered that the group, "be well fed and well clothed until opportunity offered of forwarding them to Port Curtis; from whence they are to be sent to the island from whence they were taken." Contrary to the justice and compassion of the order, the ensuing treatment of the discharged prisoners casts little merit on the colonial administration.

THE PRISONER'S FATE

Past consideration of the destiny of the three discharged men and families has been diverse. Published assertions that the accused were found guilty, sent to Moreton Bay and executed (CHAH 2017), are incorrect in light of the reports of the time and will not be further considered.

A second suggestion is that all the discharged individuals died in jail as a result of the prison diet and pining for their country (Hickling & Hickling 2005). An article on Gladstone history published 44 years after the events has a third account of the prisoners' end. The Capricornia newspaper (Variorum 1898) while providing valuable information on the

final resting place of Spurling contains so many inaccuracies, extending even to Strange's name and title, the ship he was travelling on and the names of his companions, that it might be quickly cast aside. However the final sentences provide previously unpublished information, albeit not entirely accurate, misnaming the ship and perhaps contradicting a contemporary report. The newspaper stated, "The Torch was therefore dispatched with them to the Percy Islands, and there to set them free. On the arrival of the vessel at Gladstone, the aborigines being apparently uncertain of their fate, jumped overboard during the night and made their escape. They were, however, destined to meet a worse fate. Falling in with a number of other (aboriginals) in the vicinity of Mount Larcombe, they were promptly murdered."

The reality of the ten aboriginal people's fate is a dismal mixture of some dying in gaol while others likely met a violent death near Port Curtis. On May 10, 1855 the Principal Gaoler of Darlinghurst prison wrote to the colonial Sherriff (Beverly (?) 1855). His letter stated that the aboriginals, "who were bought to this prison from the Percy Islands, are beginning to pine from their confinement, and refuse their food. One child has died, and there are two women very weak and ill." He urged a rapid removal of the party to Brisbane where a passage returning them to their islands might be more easily secured. A postscript stated, "I beg to add that there is another of their children ill, who, I am informed, will die if kept much longer in the Gaol."

In response (Moriaty 1855) on May 11, 1855, the colony's Port Master advised the Acting Colonial Secretary that "an opportunity has arisen since its receipt of forwarding to Port Curtis the Aboriginal prisoners charged with the murder of Mr Strange and others at Percy Island." The steamer William Miskin sailed for Port Curtis four days later and provided passage for an unknown number of survivors of the party at four pounds each, paid by the colonial Treasury.

A month later Maurice O'Connell, the Government Resident at Port Curtis, wrote to the Colonial Secretary (O'Connell 1855) updating him on the arrival of the aboriginals on the William Miskin on June 2, 1855 and their being initially housed and fed in the Native Police barracks. His letter included the news that the group has left the barracks and "joined the native tribes in this neighbourhood, (I) yesterday gave instructions they should be sought for again in order to see that they are not maltreated by the (aboriginals) of this place but I have not as yet heard the results." He had, "endeavoured to explain to these Percy Islanders that they are only kept here for protection and I presume if they choose as the preferable course joining the Port Curtis (aboriginals), there is no reason why I should further interfere with them." No further correspondence on the Percy Islanders has been found.

Can we judge from this distance what actually occurred? Both the government letter and the later newspaper account have the group arriving in Port Curtis and being in touch with the local aboriginal people. The Government Resident is aware of the possibility of maltreatment, and the Capricornia article identifies severe violence and the perpetrators. Richard Broome provides support for aboriginal on aboriginal deaths, "Aboriginal society was one of friends and enemies. ... Loyalty to one's kin group meant enemies have to be killed if they venture close, as they might wield sorcery, the cause of all mature deaths." (Broome 2010).

In spite of factual errors in the Capricornia account it might be given some credence being provided in part by a retired police sergeant who lived in the Port Curtis area in the 1850s. Such a presentation of the events exonerates the civil authorities and any local squatters of any responsibilities. Unknown aboriginal people are made responsible.

Even the most cursory look at race relations in this frontier area during the 1850s raises suspicions of alternative events. Violence and retribution were a tolerated part of the frontier. In 1850 hundreds of aboriginals were allegedly killed at the Burnett River, south of Port Curtis following the murder of Gregory Blaxland at Gin Gin station. The quasi-official and tolerated nature of this undertaking was shown byWilliam Walsh (a later parliamentarian) and O'Connell (later the government resident at Port Curtis) joining "others in punishing Aboriginals for the murder" (Denholm & Gibbney 1976).

The Port Curtis Pastoral District surrounding the settlement was declared in 1854. O'Connell was appointed Government Representative and quickly took up an interest in Riverton Run. Nearby was Mount Larcombe station, selected by William Young in 1854. Relations in the area between Europeans and local traditional owners were poor. Because of

the potential for conflict Native Police were regularly stationed on the Mount Larcombe property. Conflict between the parties escalated in 1854 and 1855, with shepherds, aboriginals and Native Police being killed. One report has 23 aboriginals being killed by Native Police while recovering a surveyor's stolen property (Anon. 2017).

With the widespread unrest and practice of white retribution for perceived wrongdoing by the aboriginals, is it possible that retribution could have been visited upon the discharged prisoners? For a squatter in the midst of a frontier war Chimmo's report on the deaths and his prisoners was simple and clear, "he could have arrested (them) all" for the murders. According to rough frontier justice the discharged prisoners were guilty. A distant judicial system which released the prisoners had little impact at the frontier.

Unsettling to the present reviewer is why firm arrangements were not made for the aboriginals to be protected and quickly sent to the Percy Islands. Additionally why had they been allowed to leave the Crown's protection on arrival at Port Curtis. Was there blindness or bias by the authorities? Following the recovery of Spurling's body O'Connell wrote "the funeral should be as impressive as possible in the presence of the aboriginal natives, and those of his murderers that you now have on board HMS Torch." He wished to make "an impressive ceremonial so as to lead even the untutored savage to comprehend the vastness and energy of that protective power which watches over Her Majesty's subjects even in the most remote corner of her dominions."

O'Connell had witnessed retribution upon aboriginal people, the aboriginals died "near Mt Larcombe," thus on or near, a property owned by O'Connell. Why is there no apparent follow up advice from O'Connell to the Colonial Secretary to update him about the group? The letter from O'Connell reporting "the aboriginals have left and I see no need to worry further" appears to be providing a convenient closure to an uncomfortable matter in the Port Curtis area. Members of the community apparently knew of the deaths but there is no official report? The possibility of squatter involvement is not easily dismissed.

Does anyone bear some responsibility for the deaths however caused? The role of O'Connell must be seen as questionable. The pre-judging of the accused as "murderers" gives rise to an apprehension of bias against the remaining individuals who were returned to Port Curtis. Additionally he appears to have disavowed any duty of care to the aboriginals for whom he had responsibility. Neither legal concept was a clear part of English common law at the time. Perhaps he acted to the accepted standard of the time, but it casts a shadow on a respected Queensland administrator.

What is clear is that had the compassionate orders of the Water Police Court magistrate been carried out by the colonial administration and the group returned to Middle Percy Island with some dispatch, the realised high likelihood of death would have been reduced.

CONCLUSION

Strange's zeal and commitment to natural history collecting is evident in his letters to Gould and the Earl of Derby, leaders in the natural history field of the day. His skills were sought after. He collected difficult to find and procure type specimens. Had he been able to travel as widely as some of his better known contemporaries his success might have been greater, but even so "he collected much of importance to science" (Fisher 2004).

Described as being semi-literate (Lemmer 2009) Strange overcame such a charge. He communicated by letter with some of Europe's best naturalists, collectors and taxonomists. He published in the popular press. His field notes were quoted by Gould in some of the best ornithological works the world had seen (Gould 1865:308). Strange's contribution to the Annals of Natural History on the sea snail *Myochama anomiodes* was undoubtedly edited but was published above his name (Strange 1848).

Strange has been accused of being a poor money manager (Lemmer 2009). Because he was often short of money and regularly overdrawn with Gould, poor management can be simplistically attractive. However, Strange did not have the advantage of regular employment. With six children life could not have been easy. The boarding house would have helped but there was no certain or regular income. He managed within the bounds of what he earned, he stayed in business, and he reared a family, some of whom would become prominent in the colony.

The expedition on the Vision, planned to take some three to four months, required vision, capital and management skills to put it together. Strange had

bought the ketch at a Sydney auction conducted by Messrs Bowden and Threlkeld on August 17, 1854 for £1175 (Anon, 1854). He was able to show his two apparent backers that he had the acumen to make the trip, with ten members needing to be fed and paid, a financial success. He was in his home town, continual bad money management over the previous 14 years would quickly come to the notice of even new backers and a bar to his obtaining credit.

His actions and foresight in taking out an insurance policy on his life on August 9, 1854 for six months, thereby seeking to provide assurance for his backers and his widow and children should anything go awry, is the action of a prudent manager. The life insurance policy for one thousand pounds would not be paid for five years because of conflicts between local agents and London principals. The successful court application to the English Chancellery Court in London is a tribute to the confidence and tenacity of Rosa Strange and business associate Rossiter (Rossiter v The Trafalgar Life Assurance Association 1859).

The public appeals for funds were remarkably successful suggesting that Strange had standing and respect in England as well as New South Wales. The appeals allowed Rosa and the family to purchase a small shop (Anon. 1856).

There were clear differences in the social standing and status of collector or naturalist of the time Strange succeeded as a collector and to do so needed, and acquired, the skills of the naturalist. Certainly not perfect, regularly short of money, he did not obtain the same quantities of new species as Gilbert. He faced challenges, a poor education, no patron, limited financial resources which, with a large family, curtailed his ability to mount expeditions beyond areas which had been collected for 60 years. Yet he emerges as a fine naturalist and Australian pioneer who "sacrificed his life in pursuit of natural history" (Gould 1863).

ACKNOWLEDGEMENTS

I wish to acknowledge with appreciation the cheerful support I have received from Laura Signorelli and Matthew Morgan who with incredible professionalism found new material within the viscera of the NSW State Archives and Queensland's State Library and Archives respectively.

LITERATURE CITED

ANON., 1837. Supreme Court. Sydney Gazette and NSW Advertiser, November 23, 1837:3.

ANON., 1841. Married. Sydney Morning Herald, January 28, 1841:3.

ANON., 1848a. Household Furniture and Effects. Sydney Morning Herald, Sydney, February 28, 1848:1.

ANON., 1848b. New Shell. Sydney Morning Herald, Sydney, July 17, 1848:2.

ANON., 1849. H.M. Steamer Acheron. Sydney Morning Herald, November 2, 1849:2.

ANON., 1850. Departures. Shipping Gazette and Sydney General Trade List, March 30, 1850:90.

ANON., 1851. Domestic Intelligence. Moreton Bay Courier, Brisbane, August 2, 1851:3.

ANON., 1852a. Shipping Intelligence, Bathurst Free Press and Mining Journal, Bathurst, February 18, 1852:2.

ANON., 1852b. Shipping. Moreton Bay Courier, Brisbane, March 23, 1852:1.

ANON., 1852c. Mr Strange. London Morning Advertiser, London, June 21, 1852:3.

ANON., 1852d. Mr Strange. Morton Bay Courier, November 27, 1852:3.

ANON. 1854a. Donations to the Australian Museum during the Month of July 1854. Sydney Morning Herald, August 8, 1854:2.

ANON., 1854b. Auction Business. The Empire, Sydney. August 25, 1854:4.

ANON., 1854c. Shipping. Moreton Bay Courier, September 16, 1854:2.

ANON., 1854d. Murder of Mr Strange and Three Others. Sydney Morning Herald, November, 21, 1854:4

ANON., 1854e. Return of the Ketch Vision Attack and Supposed Murder. Moreton Bay Courier, Brisbane, 25 November 1854:2.

ANON., 1855a. Donations. Transactions of the Linnean Society of London, v.21, 1855nd:351.

ANON., 1855b. Water Police Court. The Empire, Sydney, March 20, 1855:4.

ANON., 1855c. Water Police Court. Sydney Morning Herald, Sydney, April 11, 1855:5.

ANON., 1855d. To Naturalists and the Benevolent an Appeal for the Widow and Orphans of the Late Frederick Strange. Norfolk Chronicle & Norwich Gazette, December 15, 1855:1.

ANON., 1856. Subscription List. Empire, March 1856:7.

ANON., 1860. Deaths. The Sydney Morning Herald, Sydney, December 10, 1860:7.

ANON. 2017. Mount Larcombe Station Original Homestead Site. Gladstone Regional Council

Heritage Register, available at http://www.gladstone.qld.gov.au/c/document_library/get_file?uuid=a01854c5-039b-46ed-ae7b-9130feb124c0&groupId=1570002 (accessed April 16, 2017).

BEVERLEY (?), 1855. Letter from Principal Gaoler, 10 May 1855, NSW State Archives and Records, in Colonial Secretary Letters 1854-67, 4/3303.

BOWDLER SHARPE, R. 1906. Birds. The History of the Collections Contained in the Natural History Departments of the British Museum, vol 2, London 1906:493.

CHAH, 2017. Council of Heads of Australian Herbaria, Biographic Notes, Strange, Frederick (1826-1854) https://www.anbg.gov.au/biography/strange-frederick.html (accessed March 6, 2017.

CHIMMO, W. 1855. Search by H.M.S. Ship "Torch." Legislative Council, NSW, July 31, 1855:12.

CONNIFF, R. 2004. The Wall of the Dead. A Memorial to Fallen Naturalists. https://www.goodreads.com/author_blog_posts/894248-the-wall-of-the-dead (accessed March 6, 2017).

CONNORS, L. 2006. Traditional Law and Indigenous Resistance at Moreton Bay 1842-1855, Part II. ANZLH E-Journal, 2006:6.

COOTE, A. 2014. Pray write me a list of Species … that will pay me best. History Australia, Vol 11, no2, Aug 2014:80-100.

DENHOLM, D. AND GIBBNEY, H.J, 1976. 'Walsh, William Henry (1823–1888)', Australian Dictionary of Biography, National Centre of Biography, Australian National University, http://adb.anu.edu.au/biography/walsh-william-henry-4795/text7987, published first in hardcopy 1976, accessed online 1 May 2017.

EDWARDS, T. 2008. The History of the Richmond Birdwing Butterfly and its Names. Richmond Birdwing Recovery Network Inc., No 11, April 2008:4-9.

FISHER, C.T. 2004. Strange, Frederick (1810x1818-1854), Natural History Collector. Oxford Dictionary of National Biography. Oxford U P.

GOODMAN, J. 2005. The Rattlesnake. Faber and Faber, London, 2005:121.

GOULD, J. 1863. The Mammals of Australia, vol II. John Gould, London 1863:43-44.

GOULD, J. 1865. Handbook to the Birds of Australia. John Gould, London, 1865:322.

GRAY, J.E. 1854. Description of a new species of Petrogale. Proceedings of the Zoological Society of London, London, 1854:249.

HEDLEY, C. 1905a. Frederick Strange, the Conchologist. Colonial Museum Bulletin:50 – 51.

HEDLEY, C. 1905b. Results of Dredging on the Continental Shelf of New Zealand. Transactions and Proceedings of the Royal Society of New Zealand 1868 -1961:69.

HICKLING, J. & HICKLING, L. 2005. Past to Present: a History of the Percy Isles (situated off Mackay, Queensland). Authors 2005:31.

HISTORY SA 2011. (http://boundforsouthaustralia.com.au/ships/passenger-lists/cygnet-passenger-list.html). Accessed 12 July 2017.

HOOKER, W.J. 1857. Journal of Botany and Kew Garden Miscellany, London, 189.

LEMMER, L. 2009. Gould's Collectors, Australian Museum. https://australianmuseum.net.au/goulds-collectors (accessed March 12, 2017).

LINES, W.J. 1991.Taming the Great South Land, A History of the Conquest of Nature in Australia. (Allen & Unwin, Sydney): 55.

LOCH, I. 1989-90. A Strange Tale. Australian Natural History, No 3, Summer 1989-90:32.

MAIDEN, J.H. 1908. Record of Australian Botanists, Journal and Proceedings of the Royal Society of New South Wales for 1908. 42: 60-132.

MCDONALD, L. 1988, Gladstone…City that waited, (Boolarong Press, Brisbane), 1988.

MCALLAN, I.A.W. 1994. John Gilbert's Missing Months. Memoirs of the Queensland Museum, 35:155-179.

MCCLYMONT, W.G. 1940. The Exploration of New Zealand. (Department of Internal Affairs, Wellington), 1940:86.

MORIATY, E.O. 1855. Letter from Port Master, May 11, 1855. NSW State Archives and Records, in Colonial Secretary Letters 1854-67, 4/3303.

NOONAN, P. 2016. "Sons of Science": Remembering John Gould's Martyred Collectors. Australian Journal of Victorian Studies, 21.1:28-42.

O'CONNELL, M.C. 1855. Letter from Port Curtis Government Resident, July 19, 11, 1855. NSW State Archives and Records, in Colonial Secretary Letters 1854-67, 4/3303.

ROSSITER v THE TRAFALGER LIFE ASSURANCE ASSOCIATION, (1859 27 Beav 377).

SAUER, G.C. 1998. John Gould The Bird Man: Correspondence with a Chronology of his life and works, vol. 2, 1839 through 1841.

SAUER, G.C. 1999. John Gould The Bird Man: Correspondence with a Chronology of his life and works, vol. 3, Through 1845.

SAUER, G.C. 2001. John Gould The Bird Man: Correspondence with a Chronology of his life and works, vol. 4, 1846 through 1851.

SHIRLEY, J. 1917. Queensland Shells. Daily Standard, September 25, 1917:6.

STEPHENS, G.M. 1839. Discovery of a Splendid Tract at the Mouth of the Gawler River. South Australia Gazette and Colonial Register March 2, 1839:6.

STRANGE, F., 1848. Myochama anomiodes, The Annals & Magazine of Natural History etc, 2nd ser. v2 No7, London, Taylor &Francis Ltd, March 3, 1848:221.

STURT, C. 1840. Return of His Excellency... South Australian Register, January 4, 1840:3

VARIORUM, 1898. Gladstone and Its Harbour, Capricornia April 2, 1898:17.

WHITTELL, H.M. 1919. Discovery of the Toolach, or Grey's Wallaby (Wallabia Greyi), South Australian Naturalist 1919:12-13.

WHITTELL, H.M. 1947. Frederick Strange: A Biography. Australian Zoology 11 (1947); 96-114.

AUTHOR PROFILE

Pat Comben is a "retired" former Queensland Minister for Environment and Heritage. He has written for a number of popular journals on wildlife topics and the history of natural history. He was also the lead author on a peer reviewed work redefining the distribution of Procellariiformes in southeast Queensland waters.

INDICATIVE OF THE GOOD GOVERNANCE: ASSESSMENT OF THE DEGREE OF THE INHABITANTS' PARTICIPATION IN LARGE URBAN PROJECTS. CASE: MODERNIZATION PROJECT OF THE METROPOLIS OF CONSTANTINE AND MASTER PLAN OF BRISBANE

MOUHOUBI, N. & SASSI BOUDEMAGH, S.

The overall governance in the field of urban management is the result of interactions and consultations of elected representatives, employed officials and a wide range of stakeholder groups; the negotiation between them; their cooperation and interaction in the framework of the urban project and the coordination of their actions. It has the approach of "the participation" as an instrument to support participatory democracy. This new approach to urban management has spread rapidly around the world. However, it should be noted that the participatory approach was (is) not only matter of great dissemination, but also topic of research and development through the innovation of the methods and tools for its acceptance and implementation. Currently, there are several forms and ways of implementing this modern approach. In this paper, our objective is to analyze this new approach through two comparative examples, and to discuss the concept of urban project planning. The first project is the master plan of Brisbane in Australia, which involved the residents of this city in a complex process of urban transformation. The second one is the modernization of the metropolis of Constantine in Algeria. The primary objective of the present study is to assess the degree of participatory democracy and good governance. The effects of the relevant laws and regulations governing urban development of the two cities are discussed.

University Constantine 3. Constantine, Algeria; email: mouhoubi_n@outlook.com

INTRODUCTION

Throughout the world during the past several decades, there have been increasing criticisms and many public protests against the methods followed by those in charge of urban development and protection, questioning of the legitimacy of the public authorities and their ability to manage urban infrastructure on behalf of the community.

Reforms, including administrative procedures and policies on community consultation and engagement have been implemented and strengthened.

Governance in relation to urban planning is defined as "a mode of government organized on the basis of a cooperation, a partnership, or a contract between a plurality of actors as well as public private"(Human Sciences. 2004). Governance in urban management is a system of local government, which binds public institutions, social actors and private organizations in the development of collective choices to make effective the public action (Ascher. 2001).

In the development of the individualistic society and the need for modern infrastructure within a city, governance systems have become outdated and reform has been made. This introduces the need for change and reform in order to achieve balance between society development and governance systems, and more precisely reach a governance outcome which may be regarded as "good" by all those involved.

At this stage, it is no longer about the intentions of this good governance, but it is rather a question of implementation "instruments and tools" to provide for good governance.

Consideration of "urban" public action being "*any action which contributes to the development and functioning of towns and cities and agglomerations*" (Arab *et al.* 2009. P188) is an essential element of good governance in an urban development.

Problems related to governance are mainly derived

from political changes, such as the social and administrative diversity and the divergence of the visions and opinions of decision makers. The management of divergent views is an essential part in the theories of governance. Urban management throughout the world is facing common challenges, such as, the responsibilities of elected representatives, particularly mayors, the influence of professional stakeholders and city administrative staff, and often the neglect of views of city inhabitants. Therefore, to achieve good governance, it will be necessary to carefully consider the relationship between a particular urban project, and the views of all stakeholders, which is termed *an instrument of public action* (Pinson. 2005).

In addition, since governance is often represented as being the break with the traditional modes of government and management of public action, urban project management is often a break with the traditional modes of planning. Urban development projects, when properly implemented are considered as tools for the implementation of the good governance and an instrument of public action (Pinson. 1999).

In the present study, the following points are considered:

- The urban development project is an instrument of good urban governance in the framework of public action;
- Participatory democracy and more specifically civic participation is a means of the inclusive approach of mobilization of actors (stakeholders) around the urban project;
- The assessment of this stakeholder participation is critical in the evaluation of the urban project.

Urban governance in our research is related to the urban space production and the City making, not in the administration of public and economic affairs dimension. In this scope, the participation we are dealing with is also about citizen participation in the urban planning process and city production.

The present study is based on two cases:

- The urban project of Brisbane which stems from a master plan dealing with long-term urban planning.
- The urban project of Constantine which is also a strategy for long-term planning.

The long term that characterizes these two types of urban action, dealing with urban space transformation and production, refers to the multi-temporal dimension of the urban project. Knowing that, the master plan can be considered as an urban project (Berezowska-Azzag, 2012), that it proposes and implements a multitude of multidimensional (social, economic, urbanistic and environmental) and multitemporal (short, medium and long term) actions on the urban space.

METHODS

In this study, we considered the factors regarding:

- The methods of stakeholder participation in the two cities, Brisbane and Constantine; and associated countries;
- The process of implementation of the results of participation (if they exist) in the two projects including the means and tools for this implementation.

Thus, in the case of the urban project of Brisbane we used:

- The literature that described the project and its processes;
- The press reports regarding the project;
- The various websites and citizens' forums created in the framework of the participation implementation.

For the case of the urban project of Constantine, the same tools are used. However, we have also conducted a survey (since it is possible only in this case) with citizens to detect the level of participation and its role in the project. This survey has focused on a sample of 300 inhabitants of the metropolis of Constantine shared between its various municipalities.

PRESENTATION OF THE TWO CASE STUDIES

THE URBAN PROJECT OF BRISBANE (THE MASTER PLAN)

Brisbane, a large city in Australia. It is the capital city of the State of Queensland, and is one of the more attractive cities in the world. It has high urban growth; combined with a rapid population growth (expected to reach 1,150,000 inhabitants in 2026). The needs for renewable and natural resources are increasing.

An integrated development strategy that affects several areas (social, spatial, economic, environmental) has been developed. It is gradually and continuously updated in response to the challenges already cited.

The Brisbane strategy is first of all based on an information system based on planning instruments which are readily available to the general public. Consistent with the *Integrated Development Assessment System* IDAS (dilgp.qld.gov.au) (Berezowska-Azzag, 2012). It is a comprehensive system of management.

By using this system, which has been operational since 1998, a major urban project has been developed for the city. An urban project that belongs to an overall strategy is *"a territorial approach downward, ranging from the metropolitan project Global (Brisbane City Plan 2000) toward the local projects of neighborhoods (Brisbane City Center Master Plan 2026) and the neighborhood projects"* (Berezowska-Azzag, 2012). It is one of the four strategic tools of urban development until 2026. It has defined five major objectives, which are summarized: welcoming city, city in movement, green city, city at work and city protecting its identity.

This Brisbane project is rich in lessons including the overall strategy of development, and the constantly updated sustainable design, and management systems put in place.

THE URBAN PROJECT OF CONSTANTINE "MODERNIZATION OF THE METROPOLIS"

One of the most ancient cities, not only in Algeria, but also in the world, the Eastern metropolis, Constantine is a city of more than 20 centuries (2500 years). Known as the most resistant city, it has survived several centuries of wars; within a panorama of landscapes on different trays of rocks. It is the city of bridges and rocks. However, it suffers from unhealthy, frenetic and uncontrolled urbanization, fragmentation of the urban fabric, lack of infrastructure, and especially of congestion of the city center, which is in ruins.

The economic and social level, as serious as those urban ills are also poignant: unemployment, crime, social insecurity, imbalance and social segregation.

For Constantine to become a modern metropolis, a well-planned and implemented project is highly desirable if not essential.

A major urban project, the PMMC (Projet de Modernisation de la Metropole de Constantine), has been initiated to be the engine for the revitalization of the city. It has to bring life and dynamics to a metropolis in distress (Fig. 1). The objectives of the project for Constantine are divided between (Cherrad *et Al,* 2007):

- The improvement of the conditions of life and comfort (qualitative);
- The revival of the development; (competitiveness);
- The improvement of the image of Constantine (attractiveness);

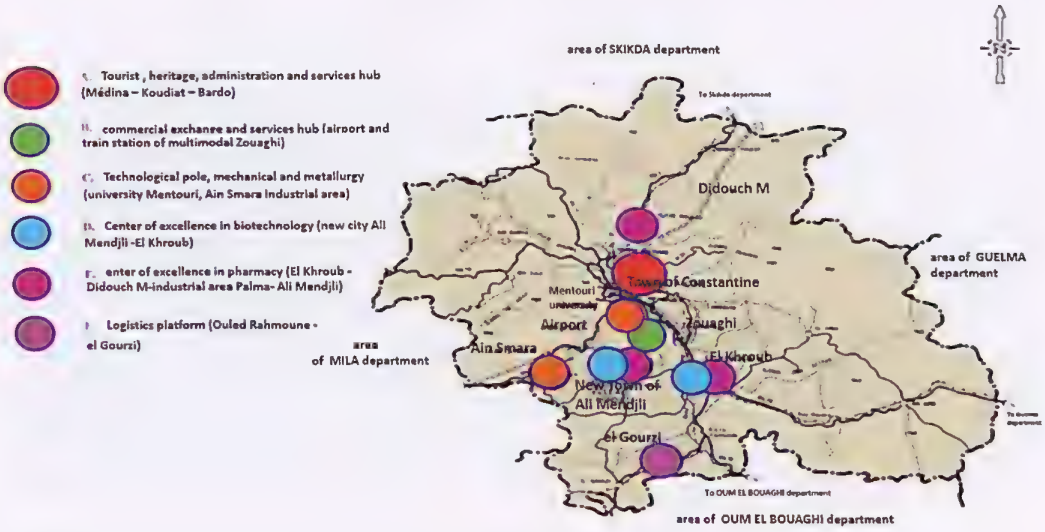


FIG.1. The major components of the Modernization (Source: Constantine, 2011 with author translation).

- The modernization; with modern equipment and particular projects;
- The realization of social equity (cohesion and reduction of disparities) and citizen participation;
- The response to the needs and the urban, economic and social crisis;
- The consistent punctual actions.

RESULTS

THE INSTITUTIONALIZATION OF PARTICIPATION IN THE TWO COUNTRIES

Participation in Australia in urban planning is highly developed. Australian methods of implementation are continuing to improve urban developments. Laws in Australia treat public participation in several fields concerning daily lives of residents, especially within their urban environment. These laws relate the various rights in relation to the participation as:

- The rights to notification;
- The right of access to information;
- The rights of application for the revision of the decisions;
- The rights of forcing a government agency to act;
- The ability to sue in court to prevent any breach of the participation rights.

So, Australia has become one of the most advanced countries for urban planning and development, not only in the field of stakeholder participation including citizen participation. Indeed, a new tool that developed at this time is e-participation or electronic participation. The tool that facilitates participation and participatory democracy in decision-making, currently *represents the most important system of participation in the world.*

In Algeria, the involvement of residents in the definition of their living environment and decision-making concerning urban development is still in its beginning. Calls for financial contributions of residents during rehabilitation operations of their homes, can be called participation.

In the Algerian regulation, several legislative texts provide the legal anchoring of participatory democracy; but the problem is the way of implementing participatory democracy. We note the specific law relative to the development and the urban planning for Constantine (law N° 90/29) requires the consultation (Article 14 and 15 of the Constitution of Algeria, which stipulates, "*the State is based on the principles of organization and social justice. The elected Assembly constitutes the framework in which is expressed the will of the people and exercises the control of the action of public authorities*", then article 16 of the same Constitution specifies, "*The elected assembly is the basis of decentralization and the place of the participation of citizens in the management of public affairs*". Finally, article 31 of the Constitution stipulates "*the abolition by the institutions of all the obstacles which impede the development of the human person and impede the effective participation of all in the political, economic, social and cultural life*".

PARTICIPATION IN THE TWO URBAN PROJECTS

THE URBAN PROJECT OF BRISBANE

The urban project of Brisbane is an example of success of the participatory approach. Actually, based on an approach of bottom-up *"where the initiative of civil society is preponderant"* (Berezowska-Azzag. 2012), participation in the project has *been institutionalized, framed, valued and personalised* (Berezowska-Azzag. 2012) (Fig. 2) by putting at the disposal of the inhabitants and users and professionals the various tools for participation (guides, manuals, codes, forums, websites). The involvement of the different stakeholders in the project has been formed in an organized manner, an important *advisory body* of stakeholder representatives has been put in place.

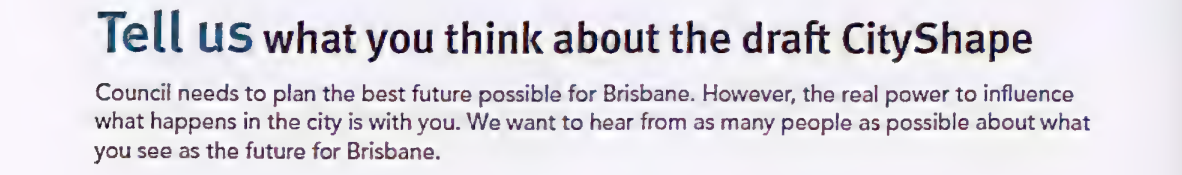


FIG. 2. Extract from the document "Draft City Shape 2026" enhancement of the opinion of the population (Source: www.brisbane.qld.gov.au).

PARTICIPATION PROCESS IN THE PROJECT

The BCC (Brisbane City Council) has prepared a plan for the development and planning of the city of Brisbane. This plan, detailed in a document called a "*Draft City Shape 2026*" has been subject to consultation of the inhabitants and others of the city providing for a *feedback* requested by BCC with the inhabitants and users of the city. All suggestions, opinions and advices on the project were welcome. This broad program of consultation began in 2005 and lasted a year, first started by information to the inhabitants on the project and then a census of the opinions in order to choose the most appropriated scenario - which the inhabitants largely supported.

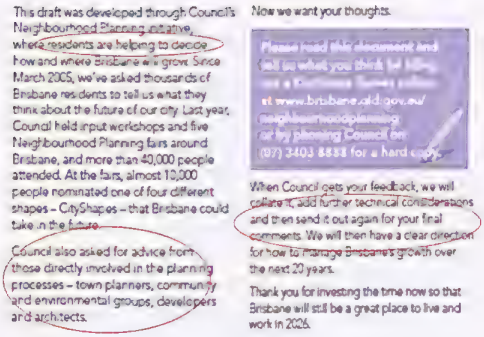
The question that has been asked is: "*How the City of Brisbane will develop in a horizon of 20 years*" (Fig. 3). The Document of "*Brisbane City Shape2026*" covers six themes of discussion on the fate of the city:

1. Calling Brisbane home "*Welcoming city*": The construction of a new vision that reflects the style of an urban-village.
2. *Keeping Brisbane moving*: The improvement of the public transport network of inter-city, roads and paths of walking that link the homes and places of work, shops, and schools.
3. *Keeping Brisbane green*: Maintenance of green spaces.
4. *Putting Brisbane to work*: To promote employment in the major commercial centers, large industries and points of specialized employment.
5. *Protecting Brisbane's identity*: Protection of the traditional characteristics of the city.
6. *Water – a precious resource*: Protection of water sources.

Feedback to the planning document was widely sought. And a response to the question of the fate of the city were the basis of the consultation program launched. Associated with workshops and consensus conferences, this program focuses on the association of the inhabitants to take decisions on the fate of their city, developing and debating several scenarios of this future. The population was targeted for comments, advices and expertise of the external users of the city and of those who live in the city. However, this program was not confined to the population, the BCC has also appealed to the competencies of the various professionals (Fig. 4).

It should be noted that this program was planned (Fig. 5) in the form of communication between policy makers and stakeholders through several rounds of participation, providing for an effective feedback. As well, more than 60,000 inhabitants have responded to this program through their ideas and comments. The response of the inhabitants of Brisbane and the users of the city to the BCC request is to implant new residences and

FIG. 3. Request for an opinion of the inhabitants and the opinions and advices of stakeholders on the various objectives of the Master Plan (Source: www.brisbane.qld.gov.au. Author treatment).


This draft was developed through Council's Neighbourhood Planning initiative, where residents are helping to decide how and where Brisbane will grow. Since March 2005, we've asked thousands of Brisbane residents to tell us what they think about the future of our city. Last year, Council held input workshops and five Neighbourhood Planning fairs around Brisbane, and more than 40,000 people attended. At the fairs, almost 10,000 people nominated one of four different shapes – CityShapes – that Brisbane could take in the future.

Council also asked for advice from those directly involved in the planning processes – town planners, community and environmental groups, developers and architects.

Now we want your thoughts.

Please read this document and tell us what you think by filling out a Feedback Survey online at www.brisbane.qld.gov.au/neighbourhoodplanning or by phoning Council on (07) 3403 8888 for a hard copy.

When Council gets your feedback, we will collate it, add further technical considerations and then send it out again for your final comments. We will then have a clear direction for how to manage Brisbane's growth over the next 20 years.

Thank you for investing the time now so that Brisbane will still be a great place to live and work in 2026.

FIG. 4. Extracts from the document "Draft City Shape 2026" (Source: www.brisbane.qld.gov.au. Author treatment).

FIG. 5. Planning of the consultation programme for the inhabitants and of the actors (Source: www.brisbane.qld.gov.au).

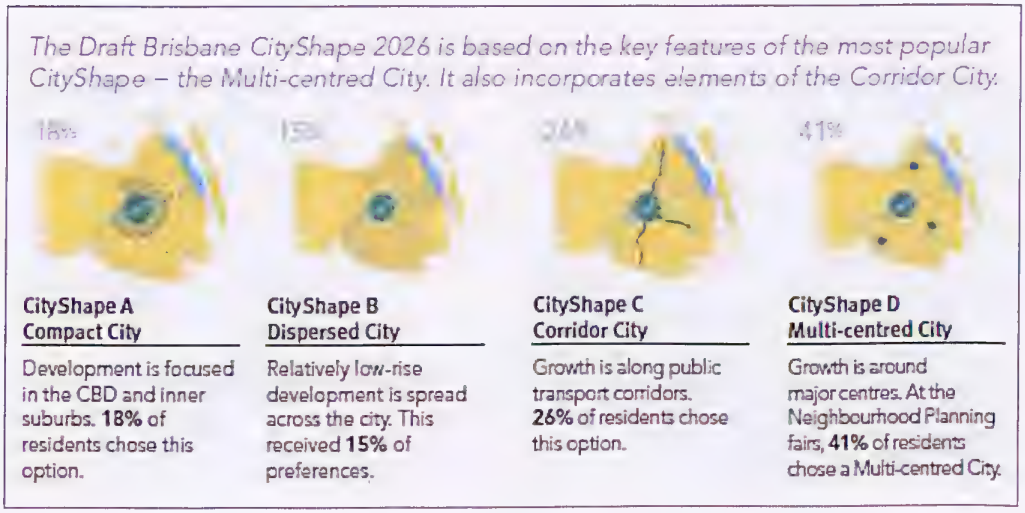


FIG. 6. The scenarios of the Draft Brisbane City Shape 2026 (Source: www.brisbane.qldgov.au).

infrastructure around the large commercial center or throughout the corridor but also to reduce the distance between places of work and residences, with greater proximity of services and easer transport system.

The different scenarios of the planning program for consultation are (Fig. 6):

- Scenario 1: Compact City;
- Scenario 2: Dispersed city;
- Scenario 3: City Corridor;
- Scenario 4: Multi-centered city.

The results of this consultation program are a vision of the future of the city that its inhabitants hope to see. The preferred scenario by the inhabitants and users of the city has been identified in 2006. It constitutes a combination between a *multi-centered city* with elements of the *corridor city*.

THE URBAN PROJECT OF CONSTANTINE

Through the present study, including the feedback on the urban project of Constantine survey of 300 inhabitants, we conclude that:

- The urban project of Constantine has not been the subject of information dissemination to the population in its majority (Fig. 7).
- Only a few people were acquainted with the project.
- The population knows about the majority of projects during implementation, however it does not know that these are part of an urban strategy as a major project of Constantine.
- The population surveyed, after learning about the objectives of the project (that we had submitted), are mostly (Fig. 8) in favor of its implementation and for its realization.
- For the surveyed population, the Urban Project of Constantine has not really brought a plus for the city Apart from the transport sector, no change has been observed.
- The survey reveals and confirms the fact that the population has not been involved in the planning and implementation of the project, even though those surveyed present willingness and readiness to be involved. They consider the best ways for an effective participation are those of delegations like associations and neighborhood committees and websites (Fig. 9). The conclusions drawn are:
- The trust between the elected, and responsible persons with the general population is very low, such that the latter does not believe in the strength of their opinion and point of view. They consider "*they are just the inhabitant*".
- The population shows a hope in the achievements and the modernization of their city, even if the urban project of Constantine represents for them an unrealistic dream.
- Two workshops have been organized in the framework of the project (January 2009 and October 2009). The first workshop was to bring together professionals and experts in order to reflect and to engage in a debate on the possible developments and scenarios of modernization, as well as consideration from experience of other cities, and finally to formalize a program for the modernization of Constantine. The second workshop aimed to submit the draft urban modernization of the metropolis to experts, researchers and professionals in order

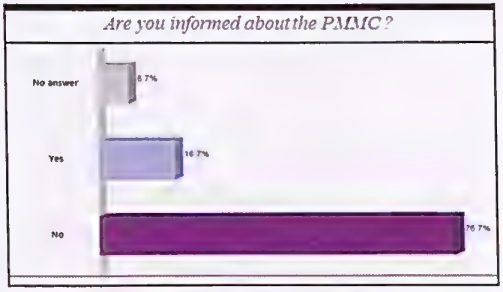


FIG. 7. The population information about the Urban Project (PMMC) (Source: Author survey of a sample of 300 inhabitants of Constantine).

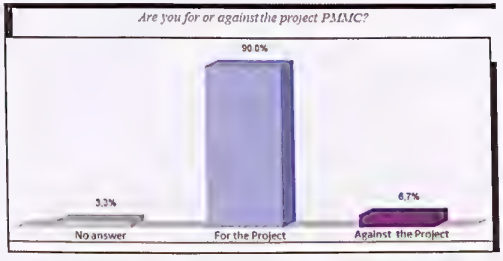


FIG. 8. The adhesion of population for Urban Project (PMMC) (Source: Author survey of a sample of 300 inhabitants of Constantine).

TABLE 1. Comparison between two urban planning projects in Brisbane and Constantine.

The indicator of comparison	Urban project of Brisbane	Urban project of Constantine
Institutionalization of participation	The participation has been institutionalized and its implementation has been developed and framed.	The participation has been institutionalized however; its implementation has not been framed.
Existence of stakeholder participation in the project	The participation in the project is existing, it is of the type top-down with the call of the BCC to the citizens involvement, this participation has been framed by this organization, consolidated by the inhabitant and planned.	The participation in the project is almost non-existent; the form of participation which tries to develop is the participation of the type bottom-up across the various manifestations and the contestation of power which appear in the context of the project from the inhabitants.
Tools of participation	• Call for the involvement of the inhabitant; • Information through the written press, audio and visual; • organization of several workshops and urban workshops; • Web site and forum with the call for the feedback	• No call to the participation; • The majority of inhabitants are not informed of the project; • organization of two workshops on the project, however, they have not been able to mobilize the inhabitant neither play the informative role; • No web site dedicated to the project or to the feedback, however, of the web pages of reviews and articles in the press around the question of participation in the project are erected.
Level of participation	More than 60 000 inhabitants has been involved and has participated in the development of the project and the choice of scenario. • Information to the consultation then the consultation through the suggestions and feedback to arrive at a high level of participation in the co-decision procedure through the collective choice of the scenario wanted.	Even the information that the first stage of the participation in the project has been omitted. No other form of participation has been noted in the project.

to evaluate and propose the Bardo Viva city and complete the proposals already made in the first workshop. However, these workshops did not involve inhabitant participation. We observed:

- A kind of revolt against the lack of participation and the lack of citizen involvement in the design of the future of the city.
- The public authorities, at their head the former wali of Constantine, bearer and initiator of the project, describes the non-participation of citizens as a constraint in the implementation of projects on time but the inhabitant did not feel himself invited to do so.

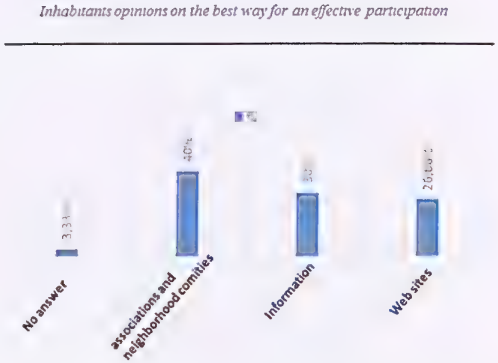


FIG. 9. The best ways to effective participation (Source: Author investigation of a sample of 300 inhabitants of Constantine).

COMPARISON BETWEEN THE TWO CASES AND REVELATION OF THE GOOD GOVERNANCE

By synthesizing the results obtained, we can draw up a comparative table of the two cases (Table 1). Based on the fact that participation was institutionalized in both countries, a large gap in the implementation is noteworthy. Indeed, stakeholder participation is a foundation in the urban planning process, and one of the stakeholders' mobilization tools around urban issues. The scenario that can be observed in the case of Brisbane is top-down participation from the general information to the public (citizens and actors of the city) towards an active participation in consultation of the inhabitants.

This is not observable in the case of the urban project of Constantine, such that the information, which is the first step of the participation, has been omitted and the most part of citizen's respondents (76.7%). These citizens were not aware of the project and its strategy nor even of its objectives.

In addition, no call to citizen involvement has been launched in Constantine and no means of participation has been implemented - except for the two workshops organized in the framework of the project, however, these workshops to create an opportunity for people to access information on this strategy and the urban project have not achieved the goal. What is noteworthy, in the Constantine case, is a certain bottom-up participation is being considered. There is currently a revolt and requests for involvement.

CONCLUSION

Urban project planning is considered as an instrument of public action and it "*occupies a privileged position in the arsenal of urban actors*" (Pinson, 2006). Thus, urban development projects as governance tools must include the participatory approach in their implementation. Participation in urban development projects has become an accurate indicator of the achievement of good governance in major cities. Through the present study of comparing urban development in Brisbane and Constantine, we can deduce that the governance system differs from one country to another but also that each urban project can choose appropriate participation methods as a means for the realization of good governance. This participation can be an asset as well as an instrument of good design and implementation of the project.

Indeed, choosing participation as a governance tool facilitates the achievement of the project and the achievement of its objectives in the best conditions. The case of Brisbane is a perfect example. Through our analysis of this case, governance includes stakeholder participation thanks to actions that have produced great results.

The case of Constantine demonstrates by its failure to achieve the goals outlined that non-participation is a factor contributing to failure in one way or another. Indeed, even if participation is institutionalized in Algeria, as in Australia, the fact that it cannot be implemented proves that even if the population is aware of its role and can help to bring all the mechanisms of good governance into operation, it does not feel invited to participate in effective action or decision-making.

Attempts to a bottom-up approach that does not often give results then straighten to weaken the will of involvement. So, the approach taken by the Brisbane project could be the outcome of this situation. Indeed, the solution would be to implement a participation of top-down type where the population would be invited to participate, this will not be quite sufficient, to take the opinions gathered into account would then promote continuity and improvement of this participation in a search for good governance.

LITERATURE CITED

ARAB N. 2001. La coproduction des opérations urbaines : coopération et conception. In Espaces et sociétés : projet urbain, maitrise d'ouvrage, commande. Ed. L'Harmattan N° 105/106. pp. 57-81.

ARAB N. IDT J. LE FLEUVE M P. 2009. Actions publiques métropolitaines : entre concurrences et coopérations. In BOURDIN A & PROST R s/d. "Projets et stratégies urbaines. Regards comparatifs" Ed. Parenthèses. 283p. PP 188-203.

ASCHER F. 2001. Les nouveaux principes de l'urbanisme. Ed. L'Aube.

BACQUE M.H. 2009. Gouvernance et urbanisme de participation. In BIAN V et TAPIE G s/d. la fabrication de la ville. Métiers et organisations. Ed. Parenthèses. Marseille. 216p. pp17-29.

BEREZOWSKA-AZZAG E. 2012. Projet urbain. Guide méthodologique. Vol 2. "Comprendre la démarche du projet urbain." Ed. Synergie. Alger.

CHERRAD S E. CHERABI A. BOULEDROUA. 2007. Projet de modernisation de la métropole

constantinoise PMMC.

DARDY C. 2008. La gouvernance urbaine ; de la théorie aux projets. Étude pour l'agence française de développement. Devisions collectivités locales et développement urbain.

JAMES R. F. BLAMEY R. K. 1999. Public participation in environmental decision-making – Rhetoric to reality? 1999 International Symposium on Society and Resource Management. Brisbane. Australia.

MASBOUNGI A. 2001 (S/dir.). Fabriquer la ville. Outils et méthodes : les aménageurs proposent. Direction générale de l'urbanisme de l'habitat et de la construction DGUHC. Club ville aménagement. La Documentation française Paris. 230p.

MASBOUNGI A. 2012. s/d. Projets urbains durables ; stratégies. Paris. Ed. Le Moniteur. 175p.

PINSON G. 1999. Projets urbains et construction des agglomérations. Echelles fonctionnelles et politiques. Les Annales de la Recherche Urbaine. N°82. pp. 130- 139. © METL.

PINSON G. 2005. Le projet urbain comme instrument d'action publique. In LASCOUMES P & GALES P s/d. Gouverner par les instruments. Ed. Presses sciences Po. 370 p. pp199-233.

GILLES PINSON. 2006. Projets de ville et gouvernance urbaine. Pluralisation des espaces politiques entre composition d'une capacité d'action collective dans les villes européennes. Revue française de science politique 2006/4. Vol. 56. p. 619-651.DOI 10.3917/rfsp.564.0619.

WILAYA DE CONSTANTINE 2007. Projet de modernisation de la métropole constantinoise PMMC. Etude réalisée par: CHERRAD S E. CHERABI A. BOULEDROUA. www.brisbane.qld.gov.au

AUTHOR PROFILES

Mouhoubi Nedjima is a PhD Student in the field of Sustainable Urban Project Management; She have been teaching in the Salah Boubnider University -Constantine 3- Faculty of Architecture and Urbanism in the Project Management Department for 2 years and in the University of Mira in Bejaia for one year. She graduated from the University of Constantine with a masters degree in project management in 2012, She undertook research in urban project management while focusing on the issues of partnership, participation, strategies of actors, and outcomes. She is also interested in urban benchmarking.

Sassi Boudemagh Souad is a Professor at Salah Boubnider University and Vice Rector of Higher Education Post Graduation, University Empowerment and Scientific Research. She has a background in architecture where she worked for more than 3 years. Being interested in research, she defended her doctoral thesis in 2006 on the formation and evolution of the architectural profession. She follows her research in many themes among others the university training and the qualities of the teaching, the urban project as well as the project management She is interested in the urban project process and implementation and assessment in Algeria's cities.

COMMUNITY EMPOWERMENT AND COOPERATION IN ENVIRONMENTAL MONITORING OF EXTRACTIVE SITES: PATHS TO A STATE-WIDE INTEGRATED SYSTEM

MARLOW, D.

In Queensland and elsewhere, there is a paucity of environmental data on abandoned extractive sites, and the public service agencies responsible for determining and monitoring the environmental conditions on these sites are inadequately resourced. There is also a paucity of publicly available environmental data on operational extractive sites (and little independent monitoring of these sites), and a lack of public trust in both the companies that conduct extractive operations and the government that oversees these operations. The requisite knowledge could be gained and much trust regained by empowering local communities and NGOs (Non-Government Organisations) to participate in joint community-industry-government environmental monitoring of extractive sites, where the results are uploaded to public-access online databases and reporting systems. The reward for the communities would be participation in the decision-making process on natural resource management issues - particularly issues relevant to extractive sites.

The environmental information relevant to decision-making on extractive sites is presently stored on multiple databases (some of which are multi-purpose databases), if it is stored at all. The value of the stored data is diminished, because it is difficult or impossible to assemble all the information required for optimal decision-making on any issue involving extractive sites. To gain important social benefits, the data needs to be integrated and made publicly available. However, if government and industry fail to heed legitimate community concerns regarding extractive sites and fail to involve communities in this joint endeavour, communities will still carry out environmental monitoring – but with the goal of gathering evidence in disputes with government and industry.

This paper defines an 'extractive site' as a 'mine site or oil/gas field'.

INTRODUCTION

PROBLEMS AND OPPORTUNITY

Governments find it increasingly difficult to adequately fund their environmental management and monitoring responsibilities, with resultant declines in governmental environmental monitoring (Buckland-Nicks, 2015; Garda, Castleden and Conrad, 2017; McKay and Johnson, 2017; Wells and Richardson, 2015). Communities have attempted to fill part of the gap with community-based environmental monitoring (CBEM) programs, but have found that the information they gather is often not used by decision-makers (Conrad and Hilchey, 2011; Murphy-Mills, 2015; Stepenuck and Green, 2015). In Australia and elsewhere, there is also a lack of public trust in the extractive industry and in government. Harvey and Bice (2014) observed that "Extractive companies are usually unpopular and generally mistrusted; there is no getting away from this". A recent study by Cameron and McAllister (2016) found that public trust in government was at its lowest since it was first measured in 1969. These problems could be largely overcome, if a cooperative partnership of government, industry, community and academia conducted data gathering on (and environmental monitoring of) extractive sites and uploaded the results to public-access online state-wide databases. This paper focuses mainly on the system of resource extraction in Queensland, but also has a wider Australian context.

THE EFFECT OF EXTRACTIVE OPERATIONS ON THE ENVIRONMENT

Extractive industries alter the environment as a consequence of their operations. The air, the soil, surface water and ground water can be contaminated, and aquifers can be over-used or depressurised. The extractive industries and the governments that approve and oversee their operations have a social obligation to reduce such environmental damage to a practicable minimum. Environments potentially adversely affected by extractive sites need to be adequately monitored, to identify and quantify any emerging environmental problems.

The monitoring needs to continue even after an extractive site has closed, because a contaminated site can leach contaminants into waterways, centuries after extractive operations have ended (Leblanc et al., 2000). Wind can blow contaminated dust from the tailings piles and waste heaps of abandoned mines into populated areas (Castillo et al., 2013; Taylor et al., 2014). The rapid development of coal seam gas (CSG) fields in Queensland has created a new monitoring imperative, because of possible interactions with usable aquifers. Aquifers and their ecosystems can't be rehabilitated, and any unforeseen consequences of CSG extraction on the Great Artesian Basin will take decades or centuries to work through the aquifers (Prosser, Wolf and Littleboy, 2011).

A LACK OF DATA, A LACK OF TRUST

THE PAUCITY OF INFORMATION ON ABANDONED SITES

The Queensland Floods Commission of Enquiry (QFCE) investigated the problems presented by abandoned mines in Queensland in a case study analysis of the contamination of Cave Creek by acid mine drainage (AMD) from the abandoned Mount Oxide copper mine site after rainfall events (QFCE, 2012). See FIG. 1. The QFCE made several cogent observations regarding the inadequacy of data collection at abandoned mines:

- It was not possible to determine the impact of the 2010/2011 floods on abandoned mines, or the resulting impact on the environment, because of the lack of monitoring and physical inspections, and information collected on those mines.
- Constraints on resources mean that the public service must prioritise the collection of information at what it knows to be high risk sites.
- To understand the hydrology of some sites, it is necessary to monitor conditions in wet and dry seasons over many years.
- Data collection is integral to appropriate management - contamination of Cave Creek might have been addressed earlier, had a systematic risk assessment and regular site inspection program been in place.
- The source of information on all known abandoned mines in Queensland is the Queensland Minerals Occurrence database, which was not specifically designed for use

FIG. 1. Contaminated creek near the abandoned Mount Oxide mine, the blue colour indicating the presence of copper precipitate in the sediment (Image source: Queensland Floods Commission Enquiry).

> in the management of abandoned mines. This database is not exhaustive. For some sites, the information is more than 40 years old. *Very few of the mines on the list have been individually inspected* (my italics). It would be useful for the Queensland Government to review the information held by all of its agencies *and seek information from the public* (my italics) to add to this database.

THE PAUCITY OF PUBLIC INFORMATION ON OPERATOR-CONTROLLED SITES

In Queensland, it is the site operator's responsibility to monitor the environmental conditions on and surrounding operating sites. The Queensland Department of Environment and Heritage Protection (2016 a; 2016 b) defines environmental monitoring for mine site rehabilitation as a company-controlled element, and ascertains whether site operators are complying with their approval conditions and other legal obligations by means of desk audits and site inspections. However, site operators are often not required to communicate monitoring data to government unless indicators exceed set limits. The Department of Science, Information Technology and Innovation (2017) does require some coal seam gas activities and coal mines to supply monitoring data on their water releases to the department to be checked against approval limits. This system of exception reporting of monitoring data and occasional government inspection, with little or no independent verification, is inherently flawed. Moreover, in Queensland, there is no public right of access to environmental monitoring data collected by site operators. When Taylor, Davies and Kristensen (2014) attempted to access data collected by Xstrata Mount Isa Mines under its environmental authority, a departmental director informed them that the department "cannot provide the mine's data to external sources without consent".

However, in New South Wales, Section 66(6) of the *Protection of the Environment Operations Act 1997* requires every holder of an environment protection licence (licensee) to make pollution monitoring data available to the public within fourteen days of obtaining the data. If the licensee maintains a website relating to the subject of the licence, the information must be displayed prominently for public consumption. Otherwise, a copy of any of the monitoring data related to pollution must be made available, at no cost, to any person who requests a copy of the data (New South Wales Parliamentary Counsel's Office, 2012).

A LACK OF COMMUNITY TRUST IN THE INDUSTRY AND GOVERNMENT

In a CSIRO survey of Australian attitudes towards mining, Moffatt, Zhang and Boughen (2014) found that the community lacked faith that governments could hold the mining industry accountable, or that legislation and regulation could be counted on to ensure that mining companies did the right thing. They also found a low level of community trust in the important actors in the mining industry in Australia, NGOs faring the best, followed by industry and the federal government, with state governments trusted the least.

The lack of public trust in government is borne out, elsewhere. Barclay et al. (2012) concluded that the unwillingness of successive state governments in New South Wales to commit additional funding to address the impacts of mining, combined with lack of trust in the state government more generally, and perceptions of a lack of local government capacity had led to heightened levels of community activism in that state. The Australia Institute's 'Greasing the Wheels' report (Aulby and Ogge, 2016) claimed that the mining industry had exerted undue influence over the Queensland and Commonwealth governments, and that this had created a "continuing malaise in public trust". It presented several case studies of mining projects gaining extraordinary access to government ministers and gaining extraordinary outcomes, including "legislative changes to remove environmental protections, federal and state government approval of projects despite serious environmental concerns, and even retrospective approval of illegal mining activities".

Gillespie et al. (2016), in a study of stakeholder trust in the Queensland CSG industry reported that external stakeholders perceived the trustworthiness of the Queensland CSG industry to be low and on par with the trustworthiness of the Queensland coal mining industry and the Queensland Government, and significantly less trustworthy than the Queensland agricultural industry. The head of one of the country's largest gas producers has warned that the nation's oil and gas industry "had lost the trust of the public" (Robins, 2017). The chief executive of the nation's peak farming body has claimed that "a deep community distrust of the sector is at the core

of state-based restrictions and moratoria on gas exploration and development", and has called on the gas industry to repair its public image if it wants a productive relationship with farmers (Australian Associated Press, 2017).

COMMUNITY CONFLICT WITH INDUSTRY AND GOVERNMENT – A TALE OF TWO COMMUNITIES

The increasing public cynicism regarding the current system of resource extraction has fuelled the growth of new activist opposition to that system, both regionally and nationally, imperilling both present and future extractive operations.

Higginbotham et al. (2010), in their study of coal-affected communities in the Upper Hunter Valley described how for twenty years, community concerns were largely ignored by authorities, residents and civil society groups who protested about air pollution and health risks were marginalised, mining industry groups sought to discredit residents' complaints, regional parliamentarians discounted residents' views, and government dependence on coal revenue from the Upper Hunter contributed to residents' scepticism. They argued that "environmental injustice and health inequity in the Upper Hunter has arisen because political economic interests outweigh concerns about long-term damage to the health of this relatively small and electorally insignificant rural population". However, they concluded that the balance of power was shifting as residents' pressure gained momentum and resonance in local government, green politics and mass media. The mounting community pressure led directly to a change in government policy – "In 2009 and 2010 there was a high level of community concern about the cumulative impact of coal mining on air quality in the Upper Hunter Region. The Upper Hunter Air Quality Monitoring Network was established in October 2010 to provide reliable, regional air quality monitoring data. By February 2012, fourteen monitoring sites were operational in strategic locations" (New South Wales Office of Environment and Heritage, 2015).

Another coal-affected community in the Lower Hunter lost its battle. The residents of the small town of Bulga fought a very public, bitter, long-running (2009 to 2017) legal dispute with Warkworth Mining Limited and the NSW Government over the expansion of the Mount Thorley Warkworth open-cut coal mine through a 'permanent' conservation zone to the town's outskirts. There was support for the expansion from larger communities, remote from the environmental consequences, but who would benefit financially from the mine's expansion (Australian Broadcasting Corporation, 2015). After the residents' legal victories in the Land and Environment Court and the state Supreme Court over the government and the company, the government changed the law to ensure that a new application by the company would succeed. The mining company promptly reapplied and the expansion over the protected area was approved (Lock the Gate Alliance, 2016). The television networks and the press widely covered the dispute over the years, with the residents portrayed in a favourable light in a dispute framed as a 'David versus Goliath' struggle. Such acrimonious public disputes fuel community distrust in both governments and the extractive industry.

There is a valuable lesson to learn from the tale of these two disputes – 'United we stand; divided we fall'. A single small community is highly vulnerable to the resource extraction agendas of remote governments and powerful corporations. A network of communities is a much more formidable foe – or much-valued partner.

COMMUNITY-BASED ENVIRONMENTAL MONITORING

PRINCIPLES FOR SUCCESS

In the context of this paper, the point of community-based environmental monitoring is to improve the management of extractive sites, so the data gathered has to be used to further this goal – preferably to be used in resource management, rather than as legal evidence in disputes.

The monitoring needs to meet professional standards of scientific rigour. Harrison et al. (2013), in a study of volunteer-gathered data in the Waterwatch ACT catchment monitoring program, concluded that "the Waterwatch database provides a good quality baseline data set for monitoring water quality in the ACT" and "The quality of Waterwatch data provides an opportunity to extend site coverage to parts of the ACT that are not well sampled at the moment". These findings mirrored those of an earlier study by Nicholson, Ryan and Hodgkins (2002) on data collected by Waterwatch Victoria volunteers. Shelton (2013) concluded that volunteer citizen scientists could collect water quality data that was not significantly different from that gathered by professionals, but that

it was necessary to select ideal parameters and provide comprehensive training. Sharpe and Conrad (2006) warned that adequate accuracy and precision could be achieved only with sufficient resources, through the use of standardised protocols, and use of Quality Assurance / Quality Control procedures.

The monitoring needs to be compatible with current government and industry monitoring, so that the community data is integrated with the government and industry data. McKay and Johnson (2017) recommended the involvement of decision-makers early in the design process to provide vision to the program, define important environmental parameters for monitoring and decide on appropriate methods of measurement to ensure data relevance and compatibility.

The monitoring needs to be sustainable. There are many suggestions in the literature about how to avoid volunteer burnout (Buckland-Nicks, 2015; Dickinson et al., 2012; Murphy-Mills, 2015; Sharpe and Conrad, 2006; Weston and Conrad, 2015). However, the best solution is for the monitoring to be done by community groups whose passion and mission is to conserve the environment and who are part of a larger state or national structure. Landcare and Natural Resource Management (NRM) groups would be well-suited to this task.

THE BENEFITS OF MULTI-SECTOR PARTNERSHIPS

A complex geographically-dispersed issue like the environmental management of extractive sites would be most effectively addressed by a cooperative partnership between government, industry, academia and community, because all groups have a stake in the issue, and all have much to contribute.

A major consequence of such a partnership could be a rebuilding of public trust in government and the extractive industry. Communities would necessarily have closer relationships with the government and the industry. Site operators and government site managers would regard the maintenance of healthy community relationships as part of daily business. This transparency and cooperation could markedly decrease the level of community disputation with the industry and government.

Government would also benefit from the extension of government monitoring networks, cost savings, promotion of public participation to achieve government goals, and provision of an early warning system of ecological changes (Sharpe and Conrad, 2006). Industry would benefit from the improved communication and relationships with communities, thereby increasing cooperation for future development activities (Noble and Birk, 2011). Universities would benefit from working relationships with government and industry decision-makers, new opportunities for societally significant scientific papers and student theses, and valuable onsite experience for staff and students. Communities would benefit from their involvement in impact management and from discussing their environmental concerns directly with industry (Noble and Birk, 2011).

TWO VOICES FROM LOCAL COMMUNITIES - MONITORING VERSUS REHABILITATION

WOWAN/DULULU LANDCARE – DEE RIVER, QUEENSLAND

The Dee River forms part of the headwaters of the giant Fitzroy River catchment in Central Queensland. Periodically, AMD from the abandoned Mount Morgan copper-gold mine has heavily contaminated the river with heavy metals. Dululu and Wowan are two small towns, located about 40 km downstream from the mine. Wowan/Dululu Landcare is a group of mostly farmers, with great concerns for the environmental health of the river. Neal Johansen, president of the group, wrote:

"Generations of locals have been driving over the Dee River bridges and guessing what colour the water was going to be on that day. As we were seeing this on a daily basis all our lives, it seemed like the norm. A Landcare meeting held in 1996....was the start of a long and arduous campaign to bring the situation at the abandoned Mount Morgan mine to the attention of the public and politicians alike.

"DNR [Department of Natural Resources] controlled the mine site and seemed to think that any interference from Landcare was a direct challenge to their authority and this proved difficult to overcome. Fortunately, Corinne Unger was then appointed head of the DNR mine site and the whole situation then changed and they were receptive to the fact that there were environmental issues that needed to be addressed. Landcare worked with DNR to bring this awareness to the politicians. Landcare held monthly meetings, many of them attended by mine staff and we attended their meetings as well, and a solid and trusting relationship

was formed and stays strong to this day..... A severe shortage of government funding is preventing the mine from being rehabilitated and there is no funding in sight. We have been unsuccessful in achieving the big picture, or shaming the government to comply... ..I think that everyone involved has developed a passion to see the best possible outcome and we have developed a strong respect for each other. We have also been lucky to have the Fitzroy Basin Association [a regional NRM group], which has been supportive in many ways" (Johansen, 2017).

KURRI KURRI LANDCARE – LOWER HUNTER REGION, NEW SOUTH WALES

Page (2013) reported that a continuing flow of AMD from the Neath Colliery site had severely contaminated a tributary of Swamp Creek and quoted a government spokesperson as saying that the seven AMD sites in the Lower Hunter had been rated as low-to-medium risk and higher risk sites were given priority for remediation funding. She went on to quote an environmental and soil scientist as saying that the acid runoff was "very toxic" and "The only real way to treat it is impound the water in a dam and treat it with super-fine lime". The Kurri Kurri Landcare group spent eight years using hydrated lime to neutralise acidic water at the Neath colliery that flowed into Swamp Creek and ultimately the Hunter River. In 2007, the Department of Lands ordered the work to stop, claiming that the group was harming the environment, because sludge was smothering the creek bed (Australian Broadcasting Corporation, 2008). In 2014, with the creek at Neath again heavily contaminated, the group wanted to resume their rehabilitation work, but permission was denied (Kelly, 2014).

Col Maybury, president of the group, wrote: "I developed automated Slaked Lime feeders that, using variable speed screw feeders, fed lime into a pumped flow of the [Neath] AMD, mixing as it flowed through launders and neutralising the acid effectively at a cost of less than 10 cents per tonne of coal. The refuse is inert and suitable for landfill disposal. We were asked to go to Greta, where a large acid spring came up the coal skip tunnel and then flowed into Anvil Creek and the Hunter River. We made an automated small plant that mixed the lime and acid and so neutralised the AMD. The resultant mix was directed by pumps onto the natural grasses and produced exceptional growth, but it was too expensive for our meagre resources". (Maybury, 2017)

He went on to describe fractious relationships with local councillors, state politicians and the public service, as the group agitated for government action to remediate the Neath site and government support for the group's own remediation work.

These voices illustrate community problems with the present system. Continual monitoring of continuing environmental problems when nothing is done to remediate the problem is deeply dispiriting and frustrating. Landcare groups have a basic drive to rehabilitate damaged environments and when their efforts are criticised and opposed by government, they too become dispirited.

DISCUSSION

PATHS OF COMMUNITY INVOLVEMENT IN GATHERING DATA AND IMPROVING MANAGEMENT ON EXTRACTIVE SITES

1. Call on the monitoring expertise of independent environmental monitoring organisations to acquire the environmental evidence needed to force improvements in government and industry behaviour – the adversarial alternative to multi-sector partnerships.
2. Supplement an existing government environmental monitoring system in an area of poor coverage.
3. Participate in citizen science environmental monitoring initiatives.
4. Participate in regional partnerships of community, government and industry in environmental monitoring.
5. Participate in a state-wide partnership of community, government and industry.

A range of organisations and initiatives were reviewed, with a view to their possible applicability to these paths (See TABLE 1).

PATH 1: THE INDEPENDENT ENVIRONMENTAL MONITORING ORGANISATION

When extractive site operators and state governments are dismissive of or hostile to legitimate community concerns, adversarial situations arise and the opportunity to create community-industry-government partnerships to address environmental problems is lost. One avenue of recourse for adversely affected communities is to gather environmental evidence, in order to apply legal or media/political pressure to effect favourable changes in corporate and political

TABLE 1. A comparison of community-oriented environmental monitoring organisations and initiatives

Title and Location	**Scale, Impact, Path(s)**	**Participants**	**Purpose**	**Important features**
Earthworks 'Community Empowerment Project' (U.S.A.)	Nation air quality 1	Non-profit activist NGO, acting on requests from communities	Empower communities to record infrared video evidence of air pollution from oil and gas activities.	**Nation-wide coverage by a single expert unit.** Tool for community empowerment. Cost-effective.
Community Science Institute (U.S.A.)	State water quality 1	Non-profit NGO, recruiting and training community groups and acting on requests from home owners	Collect water quality data to evaluate risks to waterways and groundwater. Inform communities.	**Public access to data.** Fee-for-service sample analysis (non-profit). **Financial sustainability.**
Imperial County Community Air Monitoring Network (U.S.A.)	County air quality 2	Multi-sector (community groups, local state and federal agencies, universities)	Inform the public about air quality in real time. Identify air pollution hot spots and trends.	**Public access to data.** **Long-term sustainability.** **Low-cost sensors.** **Supplements regulatory sensor network.**
Rocky View County Groundwater Monitoring Network (Canada)	County groundwater quality 2	Semi-local (community members, county council, university)	Monitor water levels to assist with long-term planning and policy development regarding groundwater resource allocation.	**Public access to data.** **Low-cost system.** Methodology can be easily adopted.
Waterwatch (NSW, ACT, Victoria)	State surface water quality 3	Multi-sector (community groups, government agencies, universities, schools, landholders)	Monitor water quality for catchment management, education and awareness-raising.	**State-wide coverage.** **Public access to data.** Continued government financial support. Multiple applications.
HLW (South East Queensland)	State Region surface water quality, catchment loads, etc 4	Multi-sector (community groups, government departments, regional councils, universities, industry, utility companies)	Improve sustainable use of land and waterways. Monitor and report on catchment and estuarine health.	Region-wide coverage. Widespread data access. **Public report card.** Includes land and water. Continued government financial support. Multiple initiatives.
FPRH (Fitzroy River Basin, Bowen Basin, Queensland)	State Region surface water quality 4	Multi-sector (community groups, government departments, regional councils, universities, extractive and agriculture industries)	Develop and implement integrated waterway monitoring and reporting.	Region-wide coverage. **Public access to data.** **Public report card.** Extensive extractive sector involvement. Continued government financial support.

behaviour. A variation of this scenario is one where communities fear present or future environmental damage from developing industries (such as gas fields) in areas where there is inadequate or no relevant publicly-available environmental monitoring data. These communities may want to monitor the present situation and create environmental baselines to prove industry culpability in the future. In these situations, a concerned community needs to call on the services of an independent environmental organisation – preferably a non-profit community-oriented NGO. Two organisations in TABLE 1 are applicable to the Australian situation and Path 1.

Earthworks (n.d.) solicits communities adversely impacted by extractive operations to tell their stories and offers possible avenues of assistance – one of which is the Community Empowerment Project, where a community can request Earthworks to supply a thermographer, equipped with a sophisticated infrared camera, to record infrared video evidence of air pollution from oil and gas activities. It may be possible to fund a similar service in Australia on a non-profit fee-for-service basis. The closest Australian equivalent of Earthworks is probably the Mineral Policy Institute (n.d.), but it is not well-funded. An alliance of conservation organisations and private donors might be able to provide seed funding or supplementary support. This concept is worth pursuing, because a single expert unit would have nation-wide coverage.

The Community Science Institute operates a state-certified water quality testing laboratory. It recruits, trains, and provides technical support for community groups to conduct long-term baseline stream monitoring. Its surface water and groundwater monitoring results are stored on public-access online data archives, so that the public and municipal and county governments can better understand and manage water resources in their jurisdictions. This non-profit NGO is financially self-supporting – testing is on a fee-for-service basis and volunteer groups are encouraged to seek funding from local sources, such as their local government authority (Penningroth et al., 2013). There appears to be no reason why this model could not be successfully adapted to the Australian situation.

There is a third possibility that could be pursued – adding a limited environmental monitoring/analysis capability to Landcare or the Natural Resource Management (NRM) state coordinating bodies. The nation-wide Landcare movement is made up of more than 5,400 volunteer local groups, who "safeguard, rebuild, regenerate, and sustainably manage the natural environment" (Landcare Australia, n.d.). The Natural Resource Management initiative is also nation-wide, with each state having a coordinating body for the regional NRMs within the state. For example, the NRM Regions Queensland (n.d.) "focuses on the state-wide delivery of regional natural resource management outcomes, in partnership with industry, community and government" and the Fitzroy Basin Association (n.d.), a regional Queensland NRM, lists its mission as "empower our region with the resources, knowledge and skills to maintain our natural assets for future generations".

Given a mandate and secure ongoing funding, the regional NRM bodies could assemble the necessary capabilities at the community level. The function would still require a state-level or national champion, but the capability itself could lie with the NRM state coordinating body, to be made available to regional NRMs on request.

PATH 2: SUPPLEMENTING GOVERNMENTAL ENVIRONMENTAL MONITORING

When a government environmental monitoring system has inadequate coverage in an area where communities have significant environmental concerns, communities may see advantage in participating in a parallel monitoring system. The parallel system would be designed either to feed monitoring data into the governmental system, or to keep the local communities informed of the local situation. Two organisations in TABLE 1 are applicable to the Australian situation and Path 2.

The Imperial County Community Air Monitoring Network is designed to fill the need for more detailed data on particulate matter in an area that often exceeds air quality standards. The five monitoring stations in the regulatory network were too few in number and not designed for community application. The community owned and operated network now produces real time data from 40 low-cost sensors. While initially funded by a federal environmental health research grant, the system is designed so that the community would have the resources, knowledge, and capacity to sustain it (English et al., 2017). This concept could work in Australia, in some circumstances. Queensland's Department

of Environment and Heritage Protection (n.d.) allows public access to hourly air quality data from its network of 29 monitoring stations. However, there has been recent controversy about what was claimed to be large gaps in the network in the central Queensland coal fields, with the government having no plans to extend its network there and the communities not having any access to mining company monitoring data (Lodge, 2016).

If extractive sector monitoring data were real-time integrated with the government monitoring data in a public-access real-time reporting system, coverage would be much improved at little cost. Such an arrangement should be regarded as part of an extractive site operator's 'social licence to operate'. However, if this essential reform is to be indefinitely delayed, low-cost community-owned-and-operated monitoring systems (preferably compatible with the relevant government monitoring system) may be required to satisfy community needs.

The Rocky View County Groundwater Monitoring Network is a simple low-cost system where community volunteers measure the water level in their wells and enter the data through a web-based data portal, which allows the public to view and download the data. It was intended as an experiment to develop a cost-effective new approach to studying groundwater resources in Alberta, using a university-municipality partnership involving community members (Little, Hayashi and Liang, 2016). This process of landholder and community augmentation of groundwater databases has particular applicability to the CSG fields in Queensland. In their study of CSG water contaminants in Queensland, Navi et al. (2015) expressed concern that there was little monitoring of the chemicals of health significance in CSG water and there appeared to be no centralised monitoring of CSG water. They concluded that a consolidated database of CSG water samples, discharges, uses and contamination incidents was required for both industry compliance and sound environmental management.

In Queensland, the Department of Natural Resources and Mines maintains an online public-access groundwater database, which stores registered water bore data (water level and flow rate) from private water bores and Queensland government groundwater investigation and monitoring bores (Queensland Government, n.d.). It would be highly beneficial to expand the groundwater network, particularly in the CSG fields. Landholders whose groundwater might be adversely affected by extractive operations and communities exposed to CSG waters would have an environmental incentive to become involved. The online station data should include all relevant data, including any measurements of salinity and total dissolved solids, and any chemical analyses (fluoride, iron, aluminium, boron, mercury, lead and benzene). Extractive industry operators also need to contribute (or be required to contribute) their monitoring data to the present public-access groundwater database.

PATH 3: CITIZEN SCIENCE ENVIRONMENTAL MONITORING INITIATIVES

Community groups who see advantage in monitoring the environmental health of extractive sites could sometimes 'piggy-back' on existing compatible, multi-purpose citizen science environmental monitoring initiatives.

One organisation in TABLE 1 fulfils the requirements for Path 3.Waterwatch (n.d.) engages communities in monitoring and protecting the health of local waterways in New South Wales, Victoria and the ACT. Waterwatch volunteers are trained in the use of standard equipment and standard data collection methods that are suitable for non-professional and professional data gatherers. The parameters measured and the method of measurement are similar (but not identical) in all three jurisdictions – see TABLE 2. TABLE 2 demonstrates that the Waterwatch monitoring program is suitable for monitoring extractive sites. The FPRH column describes a monitoring program that was designed for extractive sites. Comparison of that column with the Waterwatch columns shows high similarity in the physical-chemical indicator group, both measure phosphorus/phosphate levels, and many Waterwatch and FPRH sites measure nitrogen/nitrate levels. Participants in New South Wales conduct monthly water quality testing and optional seasonal surveys of aquatic macroinvertebrates (senior sites only) to understand and monitor the health of their rivers and to provide quality assured data. This system is appropriate for extractive sites. Extractive site monitoring at times involves testing for one or more toxicants (such as copper), which is not done in Waterwatch. Consequently, testing for toxicants would require independent analysis.

One scenario might play out as follows: a community group in a mining region of New South Wales or Victoria believes that it is in the

TABLE 2. Publicly available data on physical, chemical and biological water quality parameters

Indicator/ Parameter	Unit	HLW *	FPRH **	WW Vic	WW NSW	WW ACT
PHYSICAL-CHEMICAL						
Air Temperature Water Temperature Temperature Range	°C °C	X √ (max) √	X X X	√ √ X	√ √ X	X √ X
pH (acidity)	pH unit	√	√	√	√	√
Electrical conductivity	µS/cm	√	√	√	√	√
Turbidity (water clarity)	NTU	X	√	√	√	√
Sulfate	.	X	√	X	X	X
NUTRIENTS						
Available Phosphate Reactive Phosphorus Total Phosphorus	mg/L mg/L P mg/L	X X X	X √ √	X √ X	+ X X	X X √
Dissolved Oxygen Dissolved Oxygen Dissolved Oxygen Range	mg/L %sat	√ (min) X √	X X X	- - -	+ + X	√ √ X
Nitrates Total Nitrogen Oxidised Nitrogen	mg/L . .	X X X	X √ √	-	X	√
TOXICANTS						
Arsenic to Zinc	score	X	√(0 to 16)	X	X	X
ECOLOGY						
Macro-invertebrates Bug Numbers Species Bugs		√ √ √	√ √ √	X X X	X - # - #	X - # - #
Fish		√ √ √	X	X	X	X
Ecosystem processes		√ √	X	X	X	X

NOTES

The toxicant parameters measured would vary with the resource type, and with the studies being done.

* HLW data is widely available, but not automatically publicly available.

** The value associated with each parameter is a score out of 100. A subset of these parameters may be measured at any particular monitoring site.

√ Yes (the number of these symbols in a cell equals the number of parameters measured)

X No + Senior sites only - Some sites only

\# Separate from Water Quality Surveys; the species counted varies; used to rate stream quality.

community's interest to monitor AMD discharge from an extractive site into a local waterway; the aim is to inform the community and the government regarding the scale of the problem; the group needs help (with training, testing kits, laboratory analyses, online public access to the data gathered; the group joins the Waterwatch network. Waterwatch gains dedicated volunteers and the group becomes part of a wide network of like-minded groups. The group conducts its monitoring at the high 'data collection' standard (rather than 'awareness raising' or 'educational') and the information gathered by the group is therefore uploaded to the Waterwatch public-access online database for use in catchment management. Environmental advocacy groups would also be able to access this extractive site data and use it to campaign for remediation work on those extractive sites.

PATH 4: REGIONAL ENVIRONMENTAL MONITORING PARTNERSHIPS

Community groups who see advantage in monitoring the water quality of streams immediately downstream of extractive sites could participate in the professional monitoring program of a regional environmental monitoring partnership – if their region has one. Any new requirement to monitor extractive sites would create an additional workload, only if additional monitoring sites had to be established, or additional visits were required. The cost of incorporating this capability into an existing compatible general-purpose system would be modest, compared to that of creating a new parallel organisation.

Two organisations in TABLE 1 fulfil the requirements for Path 4 - Healthy Land and Water (HLW) and the Fitzroy Partnership for River Health (FPRH). Healthy Land and Water (n.d.) operates multiple monitoring programs over land and water, pursues multiple initiatives and offers multiple services within the region, while the Fitzroy Partnership for River Health (n.d.) focuses on water quality issues. Extractive industry activities are not a major issue in South-East Queensland catchments, but are a major issue in the Fitzroy Basin - fifteen mining and oil/gas companies operating in the basin contribute freshwater monitoring data to the Fitzroy Basin Report Card (FBRC).

The Report Card system is the preferred mechanism to summarise the state of environmental health of an ecosystem, or convey the significance of monitoring results to the public (see TABLE 3 for a comparison of report card systems). Extractive sites are point sources of pollution, and so the measurements taken at a single monitoring station can be highly significant. In addition, extractive sites sometimes require monitoring of additional indicators (the toxicants). The HLW Report Card system applies to entire waterways and is not designed to report on pollution from point sources such as extractive sites. The FPRH initiative was designed in partnership with the extractive operators in the region and the FBRC reflects this. The FPRH provides public access to the monitoring results of individual stations and this should be standard practice for all regional monitoring partnerships. However, FPRH monitoring station data have de-identified Site IDs to conform to the partnership's data sharing restrictions. This restriction needs to be lifted. The Queensland Government now provides the public with timely and free access to relevant data from many of their resource databases, and other jurisdictions require this of extractive operators, as well.

While both partnerships have gaps in their freshwater monitoring network, neither makes any use of community groups to fill the gaps. In South East Queensland, all freshwater monitoring is carried out by scientists from the Queensland Government's Department of Science, Information Technology and Innovation. In central Queensland, there are two parallel monitoring and reporting systems. In the 'professional system', partner organisations upload their monitoring data for the purpose of informing the FBRC. The community-based monitoring system is an educational and awareness-raising tool. The two systems have a degree of commonality in parameters measured, but there are inconsistencies in terminology and units. Importantly, community monitoring results are not included in the FBRC because the FPRH believes that the community-sourced data lacks the required scientific rigour and consistency (Sader, 2016). This under-estimation of community capabilities is a flaw in both monitoring systems, and should be rectified. Community-collected monitoring results can conform to high standards of scientific rigour, if effort is put into making it so (see 'Principles for success').

PATH 5: A PROPOSED STATE-WIDE INTEGRATED ENVIRONMENTAL MONITORING INITIATIVE

This paper proposes an ambitious partnership of communities, NGOs, government, extractive industry, academia and learned societies to progressively create a Queensland-wide extractive site information system. There would be multiple steps in the process.

TABLE 3. Report card grading/scoring system – freshwater component

Report Card System	Reporting Areas	Reporting Area Components	Component Indicators	Station Indicators
HLW	18 catchments • Grade • Benefits	Physical/chemical Pollutant loads Riparian Ecosystem processes Fish Invertebrates • Score	No reporting on individual indicators (such as pH or dissolved oxygen)	No reporting on individual stations (needed for point-source pollution sources)
FPRH	11 catchments • Score • Grade (+ Fitzroy Basin Grade)	Physical-Chemical Nutrients Toxicants Ecology • Score and Grade	4 Physical-Chemical 4 Nutrients 0 to 26 Toxicants 0 to 3 Ecology • Score and Grade	4 Physical-Chemical 4 Nutrients 0 to 26 Toxicants 0 to 3 Ecology • Score and Grade
Waterwatch ACT	96 reaches in 5catchment areas of 1 catchment • Grade	Component indicators are not combined into evaluated groups	4 Physical-Chemical 2 Nutrients 2 Ecology • Grade	Monitoring results on individual stations are available elsewhere.

NOTES

Waterworks benefits rating: 1 star (minimum benefits) to5 stars (maximum benefits)

Environmental Condition Grade: F (Fail or Degraded), D (Poor), C (Fair), B (Good), A (Excellent)

Score: 0.0 to 1.00 (HLW) or 0 to 100 (FPRH)

Reporting Areas:
HLW The 3 marine zones have different monitoring parameters.
FPRH The Fitzroy River Estuary and marine zones have different monitoring parameters.

1. Standardise as far as practicable the environmental monitoring indicators, testing/ sampling equipment, protocols and analysis laboratories for extractive sites.
2. Identify and prioritise gaps of knowledge on extractive sites – areas of particular community concern and areas where contamination could cause long-term damage would have a higher priority.
3. Gain extractive industry agreement to mutual sharing of data from monitoring stations – this could be a legislated requirement, but the industry would benefit greatly in public regard, if it announced this change of policy as an industry initiative.
4. Significantly increase community participation in environmental data gathering on (and monitoring of) extractive sites to professional data collection standard – especially in the priority areas.
5. Significantly expand the environmental monitoring networks, partly by means of new low-cost sensors and innovative but proven application of Information and Communication Technologies (ICT) – especially in the priority areas.
6. Upload all relevant monitoring data (community, government, industry) to appropriate groundwater, surface water and air pollution databases and the Queensland Minerals Occurrence database (or its successor) – these databases may be either state-wide or regional.
7. Create a public-access easy-to-use online extractive site inter-database data extraction and enquiry system that would constitute a virtual Queensland Extractive Site Information System.

The benefits of this approach could include greatly increased knowledge on extractive sites, greatly increased access to that knowledge, significantly improved decision-making as the 'Big Picture' emerges, increased cost-effectiveness of data gathering and monitoring, value-adding both to new data and data already gathered, focus on areas previously neglected because lack of knowledge creates lack of awareness, increased community participation in decision-making, improved relations and increased trust between the public, the extractive industry and government (with resulting declines in damaging disputes), and a greater role for universities and learned societies in improving the social fabric of Queensland.

As far as possible, this initiative would value-add to existing general-purpose environmental monitoring programs. The same monitoring groups would largely measure the same indicators with the same measuring equipment as previously (perhaps with some changes in station location), but with the added benefit of adding to the knowledge on extractive sites. This would be far cheaper, far easier to achieve and much preferable to creating and maintaining an entirely new system, with its accompanying bureaucracy and replication of functions.

There are obstacles to overcome if this proposal is pursued. A problem inherent in successful regional initiatives is that government, business and society focus attention on these regions and other regions are potentially neglected. Their very success may also delay the creation of a state-wide system, with perceived problems in integrating disparate monitoring systems and reduced urgency to create the larger system. A high degree of monitoring standardisation across regional systems is highly desirable, but standardisation need not be total - some indicators may be important in one region but not in another, or important at one station but not another. In some regions, extractive operations may not figure prominently and so only the few extractive site monitoring stations need to comply with the standardisation requirements. For example, consider TABLE 2, where it is apparent that there is a low degree of monitoring standardisation between HLW and FPRH – and the HLW sites are monitored only once a year. Because of its wide-ranging brief and limited budget, HLW concentrates on areas that require action (such as riparian zones and wetlands). It also uses catchment predictive modelling (where rainfall patterns are used to predict pollution loads in waterways) to compensate for its limited freshwater modelling. However, extractive activities are not a major source of pollution in these waterways and so only a very few monitoring stations would need to comply with any state-wide extractive site monitoring regime.

A problem inherent in embedding monitoring/reporting systems for extractive sites inside general purpose monitoring/reporting systems (such as those of HLW and FPRH) is being able to easily extract that information and link it to other relevant data held elsewhere, so that all relevant extractive site data is made available. A partnership of not-for-profit scientific organisations (such as the emerging Queensland Science Network, in Queensland) may be an appropriate custodian for this task, because the collection and dissemination of scientific knowledge is one of major functions of scientific organisations (Royal Society of Queensland, 2016). The relevant government agencies would be responsible for in-house work on their database systems.

Funding for the initiative (additional monitoring, software and hardware upgrades, management) could be raised from a small increase in the royalty on the output from operating extractive sites. Such a funding model is appropriate, because economic theory would indicate that the cost of remediating an operation should be a charge against production (i.e., the extractive industry). Funding for community-based monitoring and seed funding for community information systems could be channelled through the budget allocations for the NRM bodies. These bodies are professional and ongoing bodies that already conduct commercial services, are already agents for spending state monies, have appropriate governance arrangements in place, are already active in environmental monitoring across their regions, and are also capable of coordinating volunteer activity. Many of the volunteer groups would almost certainly be Landcare groups, which have a long-term commitment to environmental issues.

THE NEXT STEP FORWARD

There are multiple reforms that can and should be made to increase the publicly-accessible knowledge base of environmental information on extractive sites and rebuild lost public trust in government and the extractive industry. Several have been discussed

in this paper. What is needed is some mechanism whereby progress can be made on a model to achieve these reforms. Because mineral and oil/gas extraction is basically a state and territory responsibility, much of this needs to be done at a state or territory level. In Queensland, this might be achieved by the state government, the NRM Regions Queensland (representing the 14 regional NRM bodies in Queensland), the Queensland Science Network and one or more industry representatives getting together to develop a model to implement a suite of reforms.

LITERATURE CITED

AULBY, H. & OGGE, M., 2016, 'Greasing the Wheels', The Australia Institute, modified 28 July 2016, viewed 20 May 2017, http://www.tai.org.au/sites/defualt/files/P266%20Greasing%20the%20Wheels%20160726_0.pdf

AUSTRALIAN ASSOCIATED PRESS, 2017, 'Gas sector needs to rebuild trust: farmers', published 15 March 2017, viewed 30 August 2017, http://www.news.com.au/finance/business/breaking-news/gas-sector-needs-to-rebuild-trust-farmers/news-story/45ec854734da0885eeb2e86010457cf1

AUSTRALIAN BROADCASTING CORPORATION, 2008, 'Debate flares over creek acidity', ABC News, published 8 May 2008, viewed 2 October 2015, http://www.abc.net.au/news/2008-05-05/debate-flares-over-creek-acidity/2425302

AUSTRALIAN BROADCASTING CORPORATION, 2015, 'Hunter Valley residents lose battle against mine expansion', updated 27 November 2015, viewed 21 May 2017, http://www.abc.net.au/news/2015-11-27/hunter-valley-residents-lose-battle-against-mine-expansion/6980352

BARCLAY, M.A., EVERINGHAM, J., CHESHIRE, L., BRERETON, D., PATTENDEN, C. & LAWRENCE, G., 2012, 'Local government, mining companies and resource development in regional Australia; Meeting the governance challenge', Final Report, CSRM: Brisbane

BUCKLAND-NICKS, A., 2015, 'Keys to Success: A Case Study Approach to Understanding Community-Based Water Monitoring Uptake in Governmental Decision-Making', Masters Thesis, Halifax, NS, Canada: Dalhousie University

CAMERON, S.M. & MCALLISTER, I., 2016, 'Trends in Australian Political Opinion: Results from the Australian Election Study 1987– 2016', Australian National University, http://www.australianelectionstudy.org/

CASTILLO, S., DE LA ROSA, J.D., DE LA CAMPA, A.M.S., GONZÁLEZ-CASTANEDO, Y., FERNÁNDEZ-CALIANI, J.C., GONZALEZ, I. & ROMERO, A., 2013, 'Contribution of mine wastes to atmospheric metal deposition in the surrounding area of an abandoned heavily polluted mining district (Rio Tinto mines, Spain)', Science of the Total Environment , 449, 363–372

CONRAD, C.C. & HILCHEY, K.G., 2011, 'A review of citizen science and community-based environmental monitoring: issues and opportunities', Environmental Monitoring and Assessment, 176(1), 273–291, DOI 10.1007/s10661-010-1582-5

DEPARTMENT OF ENVIRONMENT AND HERITAGE PROTECTION, n.d., 'Hourly Air Quality data', viewed 28 June 2017, https://www.ehp.qld.gov.au/air/data/search.php

DEPARTMENT OF ENVIRONMENT AND HERITAGE PROTECTION, 2016 a, 'Rehabilitation requirements for mining resource activities', last modified 6 January 2016, viewed 15 August 2017, https://www.ehp.qld.gov.au/assets/documents/regulation/rs-gl-rehabilitation-requirements-mining.pdf

DEPARTMENT OF ENVIRONMENT AND HERITAGE PROTECTION, 2016 b, 'Regulatory Strategy', released 12 August 2016, viewed 15 August 2017, http://www.ehp.qld.gov.au/management/planning-guidelines/policies/pdf/regulatory-strategy.pdf

DEPARTMENT OF SCIENCE, INFORMATION TECHNOLOGY AND INNOVATION, 2017, 'Monitoring and tracking of water releases', last updated 2 July 2017, viewed 16 August 2017, https://www.qld.gov.au/dsiti/about-us/business-areas/monitoring-water-releases

DICKINSON, J.L., SHIRK, J., BONTER, D., BONNEY, R., CRAIN, R.L., MARTIN, J., PHILLIPS, U. & PURCELL, K., 2012, 'The current state of citizen science as a tool for ecological research and public engagement', Frontiers in Ecology and the Environment, 10(6), 291-297

EARTHWORKS, n.d., 'Community Empowerment Project', viewed 27 May 2017, https://www.earthworksaction.org/voices/detail/citizens_empowerment_project#.WVClWydLebk

ENGLISH, P., OLMEDO, L., BEJARANO, E., LUGO, H., MURILLO, E., SETO, E., WONG,

M., KING, G.., WILKIE, A., MELTZER, D. & CARVLIN, G.., 2017, 'The Imperial County Community Air Monitoring Network: A Model for Community-based Environmental Monitoring for Public Health Action', Environmental Health Perspectives, 125(7), 074501-1-074501-5, https://doi.org/10.1289/EHP1772

FITZROY BASIN ASSOCIATION, n.d., 'About us', viewed 27 August 2017, https://www.fba.org.au/about/

FITZROY PARTNERSHIP FOR RIVER HEALTH, n.d., home page, viewed 26 June 2017, http://www.riverhealth.org.au

GARDA, C., CASTLEDEN, H. & CONRAD, C., 2017, 'Monitoring, restoration, and source water protection: Canadian community-based environmental organizations' efforts towards improving aquatic ecosystem health', Water, 9, 212, 1-22; doi:10.3390/w9030212

GILLESPIE, N., BOND, C., DOWNS, V. & STAGGS, J., 2016, 'Stakeholder trust in the Queensland CSG industry', The APPEA Journal, DOI: 10.1071/AJ15018

HARRISON, E., DYER, F., NICHOLS, S., GRUBER, B. & TSCHIERSCHKE, A., 2013, 'Waterwatch data and catchment health indicator data review', Prepared for ACT Government, http://www.act.waterwatch.org.au/Files/Waterwatch_ACT_report_final.pdf

HARVEY, B. & BICE, S., 2014, 'Social impact assessment, social development programmes and social licence to operate: tensions and contradictions in intent and practice in the extractive sector', Impact Assessment and Project Appraisal, 32(4), 327–335, http://dx.doi.org/10.1080/14615517.2014.950123

HEALTHY LAND AND WATER, n.d., home page, viewed 23 June 2017, http://hlw.org.au

HIGGINBOTHAM, N., FREEMAN, S., CONNOR, L. &. ALBRECHT, G., 2010, 'Environmental injustice and air pollution in coal affected communities, Hunter Valley, Australia', Health and Place, 16(2), 259-266

JOHANSEN, N., 2017, Private Communication, 10 June 2017

KELLY, M., 2014, 'Kurri Landcare wants to clean old Neath mining site', Newcastle Herald, published 18 November 2014, viewed 1 October 2015, http://www.theherald.com.au/story/2705766/landcare-plea-let-us-clean-old-mine-site/

LANDCARE AUSTRALIA, n.d., 'About', viewed 5 September 2017, https://landcareaustralia.org.au/about/

LEBLANC, M., MORALES, J.A., BORREGO, J. & ELBAZ-POULICHET, F., 2000, '4,500-year-old mining pollution in southwestern Spain: long-term implications for modern mining pollution', Economic Geology, 93, 655-662

LITTLE, K.E., HAYASHI, M. & STEVE LIANG, S., 2016, 'Community-Based Groundwater Monitoring Network Using a Citizen-Science Approach', Groundwater, 54(3), 317-324

LOCK THE GATE ALLIANCE, 2016, 'Lock the Gate challenges Minister Stokes to urgently restore legal appeal rights as Bulga residents withdraw challenge in Land & Environment Court', published 20 May 2016, viewed 31 August 2017, http://www.lockthegate.org.au/stokes_restore_merits_appeals_bulga

LODGE, J., 2016, 'Central Queensland mining communities at risk due to 'next to no monitoring' of toxic pollution: expert', ABC news, last updated 15 January 2016, viewed 27 June 2017, http://www.abc.net.au/news/2016-01-15/air-pollution-monitoring-near-qld-mining-communities/7089060

MCKAY, A.J. & JOHNSON, C.J., 2017, 'Identifying Effective and Sustainable Measures for Community-Based Environmental Monitoring', Environmental Management, 60, 484–495

MAYBURY, C., 2017, Private Communication, 29 May 2017

MINERAL POLICY INSTITUTE, n.d., 'About us', http://www.mpi.org.au/about/

MOFFATT, K., ZHANG, A. & BOUGHEN, N., 2014, 'Australian attitudes towards mining: Citizen survey – 2014 results', CSIRO Australia. EP 146276

MURPHY-MILLS, E., 2015, 'Community-based water monitoring: a case study of the Oak Ridges Moraine, Ontario, Canada', Masters Thesis, Kingston, Ontario, Canada: Queen's University

NAVI, M., SKELLY, C., TAULIS, M. & NASIRI, S, 2015, 'Coal seam gas water: potential hazards and exposure pathways in Queensland', International Journal of Environmental Health Research, 25(2), 162-183

NEW SOUTH WALES OFFICE OF ENVIRONMENT AND HERITAGE, 2015, 'Upper Hunter air quality monitoring network - what is measured', last updated 13 November 2015, viewed 27 August 2015, http://www.environment.nsw.gov.au/aqms/uhaqmnfaq.htm

NEW SOUTH WALES PARLIAMENTARY COUNSEL'S OFFICE, 2012, 'Protection of the Environment Operations Act 1997 No 156', https://www.legislation.nsw.gov.au/inforce/35a71851-d0d2-4b8c-fb85-a6382a46e66f/1997-156.pdf

NICHOLSON, E., RYAN, J. & HODGKINS, D., 2002, 'Community data-where does the value lie? Assessing confidence limits of community collected water quality data', Water Science and Technology, 45(11), 193-200

NOBLE, B. & BIRK, J., 2011, 'Comfort monitoring? Environmental assessment follow-up under community–industry negotiated environmental agreements', Environmental Impact Assessment Review, 31(1), 17-24

NRM REGIONS QUEENSLAND, n.d., 'About Us', viewed 29 November 2017, nrmrq.org.au/about-us

PAGE, D., 2013, 'Creek poisoned by acid from old mines: photos', Newcastle Herald, published 17 September 2013, viewed 1 October 2015, http://www.theherald.com.au/story/1783248/creek-poisoned-by-acid-from-old-mines-photos/

PENNINGROTH, S.M., YARROW, M.M., FIGUEROA, A.X., BOWEN, R.J. & DELGADO, S., 2013, 'Community-based risk assessment of water contamination from high-volume horizontal hydraulic fracturing', New Solutions, 23(1), 137-166

PROSSER, I., WOLF, L. & LITTLEBOY, A., 2011, 'Water in mining and industry', in Prosser I (ed.), Water: Science and Solutions for Australia, CSIRO, Australia.

QFCE (QUEENSLAND FLOODS COMMISSION OF ENQUIRY), 2012, 'Final Report: Chapter 13 – Mining', viewed 20 July 2015, http://www.floodcommission.qld.gov.au/__data/assets/pdf_file/0017/11717/QFCI-Final-Report-Chapter-13-Mining.pdf

QUEENSLAND GOVERNMENT, n.d., 'Groundwater Database - Queensland', viewed 28 June 2017, https://data.qld.gov.au/dataset/groundwater-database-queensland

ROBINS, B., 2017, 'Gas industry has 'lost the trust of the public'' The Sydney Morning Herald, released 15 May 2017, viewed 30 August 2017, http://www.smh.com.au/business/energy/gas-industry-has-lost-the-trust-of-the-public-20170515-gw50vd.html

ROYAL SOCIETY OF QUEENSLAND, 2016, 'Queensland Science Network', viewed 27 June 2017, http://www.royalsocietyqld.org/2016/11/science-queensland-2/

SADER, P., 2016, 'The Value of Community Based Monitoring in Integrated Water Management of the Fitzroy Basin', University of Queensland School of Chemical Engineering (Master of Integrated Water Management Thesis), published 2 June 2016, viewed 26 June 2017, http://riverhealth.org.au/wp-content/uploads/2017/01/PascaleSader_FINAL_Thesis_Updated-1.pdf

SHARPE, A. & CONRAD, C., 2006, 'Community based ecological monitoring in Nova Scotia: challenges and opportunities', Environmental Monitoring and Assessment, 113, 395–409

SHELTON, A.M., 2013, 'The accuracy of water quality monitoring data: a comparison between citizen scientists and professionals', Masters Thesis, Halifax, NS, Canada: Saint Mary's University.

STEPENUCK, K.F. & GREEN, L.T., 2015, 'Individual- and community-level impacts of volunteer environmental monitoring: a synthesis of peer-reviewed literature', Ecology and Society, 20(3): 19, 1-16

TAYLOR, M.P., DAVIES, P.J. & KRISTENSEN, L.J., 2014, 'Licenced to pollute but not to poison: The ineffectiveness of regulatory authorities at protecting public health from atmospheric arsenic, lead and other contaminants resulting from mining and smelting operations', Aeolian Research , 14, 35-52

TAYLOR, M.P., MOULD, S.A., KRISTENSEN, L.J. & ROUILLON, M., 2014, 'Environmental arsenic, cadmium and lead dust emissions from metal mine operations: Implications for environmental management, monitoring and human health', Environmental Research, 135, 296-303)

WATERWATCH AUSTRALIA, n.d., 'What is Waterwatch?', viewed 8 June 2017, http://www.waterwatch.org.au

WELLS, P.G. & RICHARDSON, D.H.S., 2015, 'The growing role of citizen science in monitoring environmental change – achieving a balance with government programs?', Proceedings of the Nova Scotian Institute of Science, 48(1), 1-3

WESTON, S. AND CONRAD, C., 2015, 'Community-based water monitoring in Nova Scotia: solutions for sustainable watershed management', Environment and Natural Resources Research, 5(2), 1-13

AUTHOR PROFILE

The author began his career as a milling metallurgist with Mount Isa Mines at Mount Isa, before returning to the University of Queensland to complete his M.Sc. He then worked on Hamersley Iron's financial modelling system, before returning to Brisbane to work for MIM Holdings as a Technical Computer Analyst. He later worked in the Queensland Public Service, holding the position of Principal Research Adviser at his retirement. He has lately involved himself in investigating the benefits to be derived from the involvement of communities and professional organisations in what he regards as the increasingly important issue of site rehabilitation.

ANNUAL REPORT, ROYAL SOCIETY OF QUEENSLAND, 2016 – 2017

OVERVIEW

This report covers the period from late August 2016 to end September 2017. The Society has again had an active year with several inspiring events as well as timely publication of our journal, Proceedings of the Royal Society of Queensland Volume 121.

Perhaps the most significant happening for the year is the least prominent. The work program of the Society in the past couple of years has brought to attention two significant features of Queensland's scientific landscape. One is the range of issues in which central coordination by government is weak. In mine rehabilitation, in science education, in climate change and almost every other topic we have touched, the different public and private sectors involved tend to publicly advocate their own solutions to contemporary issues with inadequate cross-disciplinary debate.

The second is the absence of any other prominent spokesperson for evidence-based policy analysis in public affairs in this new era of "alternative facts". The Society and the Queensland Academy of Arts and Sciences are about the only two Queensland-specific entities able to speak for the application of scientific method to contemporary issues.

Given these observations, and fortified by a grant from the Office of the Queensland Chief Scientist to strengthen the bridges between science and policy, the Society's mission has been tweaked to emphasise its role as a learned society, concerned with rational evidence-led intellectual enquiry in all disciplines, not just the natural sciences. This modest change in wording reverts to the mission of the Society at its foundation in 1884 and has evolved without any expressed objection from the membership.

CORPORATE AFFAIRS

MEMBERSHIP

As of September 2017, the Society has 90 fully paid up members with another 20 due for renewal.

ROYAL SOCIETY OF QUEENSLAND COUNCIL MEETINGS

The Council elected at the Annual General Meeting comprised Angela Arthington, Geoff Edwards as President, Ross Hynes as Assistant Secretary, Ben Lawson as Secretary, Bill McDonald who returned as Treasurer, Barry Pollock as Editor, Nita Valerie Sharp, and Craig Walton as Immediate Past President. During the year leave of absence was granted to Bill McDonald to volunteer in Borneo and to Ross Hynes for a short period for medical leave.

Two meetings of Council were held on 11 December 2016 and 16 July 2017.

FINANCES

Generous donations were received from Prof Trevor Clifford and Dr Ross Hynes towards the running costs of the Society. Another special donation was received to establish a website for the Queensland Science Network. The series of briefings on Science for Decision-makers has enabled the Society to raise its activity and its profile to another level, but the grant will run out in February 2018.

LIBRARY

Honorary Librarian Meg Lloyd has continued to curate the Society's library of some 20,000 volumes housed at the Queensland Museum. Members enjoy free access to the Society's library, by appointment with Ms Lloyd.

PROCEEDINGS OF THE ROYAL SOCIETY OF QUEENSLAND

Honorary Editor Dr Barry Pollock oversaw the production of Volume 121 of the Proceedings of the Royal Society of Queensland and upheld the high standard of this journal of record, the pre-eminent generalist journal for publishing Queensland-specific natural science. Thanks to Mr Rennie Fletcher for type-setting and layout of the journal articles. All papers submitted for publication in the Proceedings are subject to review by anonymous referees who are experts in the particular subject area of the submitted paper. The labours of the anonymous referees are very much appreciated.

SCIENCE FOR DECISION-MAKERS

In January 2017, the Society received advice from the Office of the Queensland Chief Scientist that a grant of $7500 had been approved under the Engaging Science program to deliver a series of briefings for leaders in government, business, academia and the community on how to incorporate science into decision-making and policy-making. This is a landmark project with

high stakes. Among other things, it enabled the Society to employ an Events Secretary. Cathy Collins was appointed first and after she resigned in the middle of the year, Pam Lauder was appointed in her place.

The following events have been triggered and/or expenses covered by this grant:

- a panel discussion with the Australian Institute for Company Directors on 27 April 2017 on emerging climate and sustainability risks that company directors need to consider, and how sustainability reporting requirements may be addressed;
- two briefings at Parliament House of MPs and their advisors (11 May 2017, 7 September 2017), the first on finding the public interest through scientific method; the second on reform of the electricity regime;
- a presentation in Townsville on 19 May 2017 to the Ambassadors Council overseeing the implementation of the *Queensland Plan*;
- a lunchtime forum on 8 September 2017, aimed at public servants and policy analysts on electricity reform, followed by a deliberative workshop aimed at producing a set of principles to guide the Department of Energy and Water Supply in crafting new electricity legislation. The workshop was co-hosted with the TJ Ryan Foundation.

The Society acknowledges with gratitude the approval of The Speaker, the Hon Peter Wellington MP, for the use of a room at Parliament House for four briefings. The attendance of the Hon Leanne Enoch MP, Minister for Innovation Science and the Digital Economy at the first briefing is appreciated.

EVENTS

LAUNCH OF ASSA REPORT ON COMPARATIVE ADVANTAGE – 7 SEPTEMBER 2016

The Academy for the Social Sciences in Australia featured at an event in the Auditorium of Queensland Museum co-hosted by the Academy for Technological Sciences and Engineering and the Royal Society of Queensland, to publicise a new report on potential opportunities for Australia to develop comparative advantage, notably through research and innovation. The report is the culmination of a three year long project – "Australia's Comparative Advantage", a project chaired by ASSA's current president, economist Prof. Glenn Withers AO FASSA. Prof Withers delivered the primary address. Member Prof Ian Lowe AO FATSE as co-respondent pointed out the biophysical limits to economic growth and the constraints upon throughput of resources and materials from the Australian environment.

ROYAL SOCIETY OF QUEENSLAND ANNUAL GENERAL MEETING – 28 OCTOBER 2016

The Annual General Meeting of the Society was held in the Gardens Point Campus of Queensland University of Technology. We were privileged to hear member Assoc. Prof (Climatology) Joachim Ribbe, University of Southern Queensland, as guest speaker on Australia's blue economy and the role of marine research. Prof Ribbe briefly reviewed Australia's *Marine National Plan 2015-2025*. He described sand movements and currents of Queensland's east coast, in the context of relentless climate change.

EDUCATION BRAINSTORM ON TEACHER PREPARATION – 17 NOVEMBER 2016

The Society along with the Academy of Technological Sciences and Engineering sponsored a brainstorm to focus on the preparation for teaching science that universities give to their undergraduates in the education faculties. This followed from the education brainstorm a year earlier.

Approximately 30 educators attended and heard first a keynote presentation from Prof Ken Wiltshire, co-convenor of the 2014 Australian Curriculum Review, then presentations from the science and education faculties from the three metropolitan universities.

DINNER MEETING 24 MARCH 2017

Some 17 members and guests enjoyed a meeting and dinner at the Hotel George Williams to celebrate the investiture of Emeritus Professor Trevor Clifford as Honorary Life Member. Council member Dr Ross Hynes spoke of Prof Clifford's influence in the early stages of his career, and of "a generation of other scientists"; and Prof Ray Specht tabled a chronicle of Prof Clifford's achievements.

The RSQ President and member Michael Gutteridge delivered addresses on the theme of "Scientific Method in an Era of Alternative Facts".

QUT SCIENCE STUDENTS' ASSOCIATION – 13 APRIL 2017

The President was invited to join a panel discussing the subject "Science and ethics" organised by the Science Students' Association at Queensland University of Technology.

SIR TIMOTHY GOWERS' AFTERNOON TEA – 29 JUNE 2017

Eminent expert in open-access publishing Sir Timothy Gowers, Fellow of the Royal Society of London, addressed a meeting of about 70 members and guests of the Society along with staff and volunteers from the State Library of Queensland on 29 June. We were honoured by the presence of the State Librarian, Ms Vicki McDonald.

RSQ WEBSITE

Member Gary Hopewell established and is moderating a Society Facebook page. All members are invited to take advantage of this excellent opportunity to distribute snippets and announcements about current events. A link is available on our homepage.

Software bugs within the search engine that taps into the archive of Proceedings back to 1859 were ironed out by web developer Clear Media on instructions from our sponsor Avantix. The next stage in development of this archive is to proofread the scanned files which for issues prior to 2007 were created by scanning printed copies and which therefore contain spelling errors. Volunteer Louise Johnson has offered to commence the task of proofreading and the State Library of Queensland is assisting to set up this process.

Current policy is to make issues prior to 1956 available free of charge, but to seek payment for articles after that – except for members, who can enjoy free access to any issues. The Melbourne-based agency Informit handles requests for articles for which a charge is made.

Supported by sponsor Avantix, the Society's website was upgraded to include a facility for members to pay their membership fees or subscription online by PayPal or credit card without needing to make a bank transfer or send a cheque.

PROJECTS

RESEARCH FUND PROSPECTUS COMPLETED

The Society's pro bono lawyers Sparke Helmore endorsed the wording of a prospectus on which we hope to solicit philanthropic donations towards funding research by scientists and naturalists that would otherwise pass below the radar of the mainstream grant programs. All members are encouraged to read the prospectus and distribute it amongst their networks. Members of retirement age are invited to remember this fund during their estate planning. The fund is tax deductible and naming rights are available for significant bequests.

STEM EDUCATION NATIONAL PORTAL LAUNCHED

A national STAR portal for science educators https://www.starportal.edu.au/ was opened during the year. The portal, developed by the Australian Chief Scientist, gives access to a structured repository of materials and other resources that teachers of science in primary and secondary schools can use in their classrooms. It is the end product of a long period of gestation that commenced with an initiative by the Royal Society of Queensland in 2014.

GENOMICS COLLABORATION

During the year, the Society was approached by the China National GeneBank (CNGB) based in Shenzhen China with an offer of sponsorship for genomic analysis. CNGB is a non-profit organisation funded by the Chinese Government and an element of the Beijing Genomics Institute.

CNGB advised that it is committed to developing a biobank consortium worldwide to provide a platform for information sharing and exchange of biobank materials, omics data acquisition, and multi-omics scientific research. Their email listed interests in genomics and bioinformatics research and bioconservation, in terms of plants (bilateral germplasm exchange, seed sequencing), animals (bird, vertebrates, ants sequencing, endangered mammal conservation), marine organisms (coral, deep-sea organisms, adaptive evolution), palaeobios (ancient dinosaur, sheep, pig, human) and related topics.

RSQ Council resolved not to enter contracts directly, but to canvass members who might benefit from this offer. One members university has taken up the offer and negotiations are at an advanced stage. The Office of the Queensland Chief Scientist agreed to handle geopolitical negotiations.

This Annual Report was compiled by Dr Geoff Edwards, President Royal Society of Queensland.

OBITUARY OF DR ALAN BARTHOLOMAI AM
1938 - 2015

Queensland lost one of its giants in science and the Royal Society of Queensland lost one of its most eminent members when Dr Alan Bartholomai AM passed away on 17 December 2015.

Dr Bartholomai qualified in geology in 1960 and the same year was appointed Curator of Geology at the Queensland Museum. In 1969 he was appointed Director of Queensland Museum, a role he held from 1969-1999, becoming the longest serving Director in the Museum's history. During his time as Director, Dr Bartholomai oversaw the relocation of the Queensland Museum from the Fortitude Valley site to its current location at the cultural precinct at South Bank. In 1986, by the time the Museum had been relocated, it had become a world class organisation with a 100-strong staff, six times the size it had been when Dr Bartholomai first became Director. It had become a museum which was keeping pace with changing philosophies and advances in science and technology; an innovative organisation able to appeal to all aspects of public need, attracting the support of the Government and the community.

Following his retirement, Dr Bartholomai continued his connections with the Museum, not only as a Board Member for the Cobb & Co. Museum, but through his research. A renowned authority on Cretaceous-era fish and Cenozoic marsupials, Dr Bartholomai is also well-known by the public for his work in describing the Australian dinosaur *Muttaburrasaurus* with Ralph Molnar.

During the early years of his career, he was mentored by other eminent members of the Royal Society of Queensland including Jack T. Woods and Dorothy Hill. During this period he was also active within the Royal Society, being elected to Council in 1966, 1967, 1968; serving as President in 1970 and Vice-President in 1971; and again serving on Council in 1972.

He was an ongoing member of the Royal Society for the whole of his time at the Museum. During his year as President his presidential address was on the evolution of the kangaroos, a subject of particular interest to him as it formed the research focus for his Doctorate of Philosophy.

Dr Bartholomai was awarded a Member (AM) of the Order of Australia in the General Division "For service to the advancement of science, particularly through administrative roles with the Queensland Museum."

He will be remembered by those who knew him for his great story telling and irreverent humour and self-deprecating wit. A more comprehensive obituary which documents Dr Bartholomai's contributions to the Museum and his research has been written by Dr Andrew Rozefelds, Head of Geosciences Program, Queensland Museum and has been published in the *Memoirs of the Queensland Museum - Nature*, vol 60, in 2017.

As the published obituary mentions, Dr Bartholomai, "with the major support of the QM Board and an excellent and highly committed group of professional staff and volunteers, oversaw this transformation into the Museum that we largely know today. Alan helped open the doors to make the Queensland Museum, at a whole range of levels, into a more open and accessible institution for all Queenslanders."

The Royal Society of Queensland is gratified that the collaboration between the Society and Queensland Museum fostered by Dr Bartholomai remains strong today.

Prepared with the assistance of Dr Bartholomai's daughter Leigh Coyle and Dr Andrew Rozefelds.

CONTENTS

JRNL N36-N38